
MACHINE DESIGN
March 1953
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MACHINE DESIGN

March 1953, Vol. 25—No. 3

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Over the Board

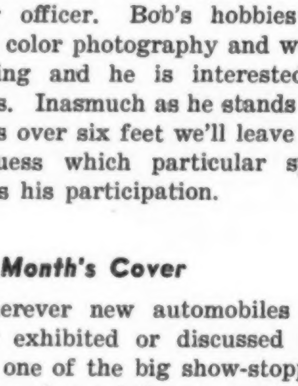
Meet Bob Rodgers

A new addition to the staff of MACHINE DESIGN is Robert C. Rodgers, assistant editor, whose picture appears on Page 202. A native Hoosier, Bob graduated from Purdue in 1949 with a B.S. in electrical engineering. Prior to coming with us he spent four years in the design and development of visual research apparatus for the G. E. lamp division at Nela Park. His stint for Uncle Sam included two years in the Navy as electronic technician, much of that time being spent with minesweeping operations along the coast of China and Japan, and he now holds a commission in the Naval Reserve as a radar officer. Bob's hobbies include color photography and woodworking and he is interested in sports. Inasmuch as he stands two inches over six feet we'll leave you to guess which particular sport claims his participation.

This Month's Cover

Wherever new automobiles are being exhibited or discussed this year, one of the big show-stoppers is the glass-reinforced laminated plastic body. For the first time the large automotive manufacturers are actually offering such bodies to the public, which is definite indication that this material has now come of age. Our front cover this month is a sort of salute to plastic laminates prompted by these new developments and by Boeing engineer Robert King's article which begins on Page 112.

Incidentally, this is one of the subjects included in Boeing's "Process Tips" program. As with other materials and processes, a display board is set up at a strategic point in the engineering department where it can be seen by all engineers. Exhibits illustrate design principles and typical applications, and bulletins on the process are available for interested designers.



Your Magazine

In recent months some of you have been interviewed by representatives of the Eastman Research Organization, which is making studies of how MACHINE DESIGN is being read and what values design engineers are receiving from it. It is part of our plan to maintain MACHINE DESIGN as your professional journal, and we appreciate the time and thought which you have given to answering our questions. Although we do tailor our editorial material to your expressed desires, we don't stop at that, as you will see from Colin Carmichael's editorial on Page 103.

Dare To Compare

You will recall the "Dare To Compare" advertisements which appeared recently in MACHINE DESIGN, showing a blindfolded man assembling a Westinghouse Lifeline starter. Through the courtesy of the manufacturer the editors were given an opportunity to test their skill (or, perhaps, the ease with which the starter could be put together) by assembling one themselves. The course came in seven easy lessons but we must confess we weren't able to do it blindfolded—not the first time, anyway.

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MACHINE DESIGN
MARCH 1953

Recipe for Leadership

AS POLITICIANS and others are fond of declaring, with apparent satisfaction, this is the Age of the Common Man. But the more thoughtful are asking, how can we avoid an accompanying degradation of intellectual standards leading ultimately to an Age of Mediocrity?

Those who control the mediums of mass education and entertainment—books, magazines, newspapers, theater, movies, radio, television—seem content merely to cater to their conception of mass demand rather than trying to elevate public taste. After all, as responsible business people they can't be expected to risk going broke performing noble experiments. But when some educators who should be taking the lead in elevating standards no longer concern themselves so much with what should constitute a good education as with what the students seem to want, what hope is there of halting the downward trend?

Writing in *The Saturday Review,* Joseph W. Krutch comments at length on the foregoing points and concludes that the most important social task of thinkers and educators today is to "define democratic culture in some fashion which will both reserve a place for uncommon excellence and, even in connection with the largest masses, emphasize the highest rather than the lowest common denominator."

Although the readers of MACHINE DESIGN are not to be compared with "the largest masses" there is a parallel, and it would be easy for us as editors to persuade ourselves that we should publish only what the statistically average reader thinks he wants or can fully understand.

But what of the real needs of an expanding design engineering profession and of the uncommon men who are taking the lead in creative developments? These needs will be satisfied only by a bold policy of presenting challenging articles which pioneer into new realms of thought and action. It has been gratifying that more and more of the forward-looking leaders of our profession, both here and abroad, are recognizing this as MACHINE DESIGN's editorial policy and are offering for publication in our columns the findings of their advanced thinking.

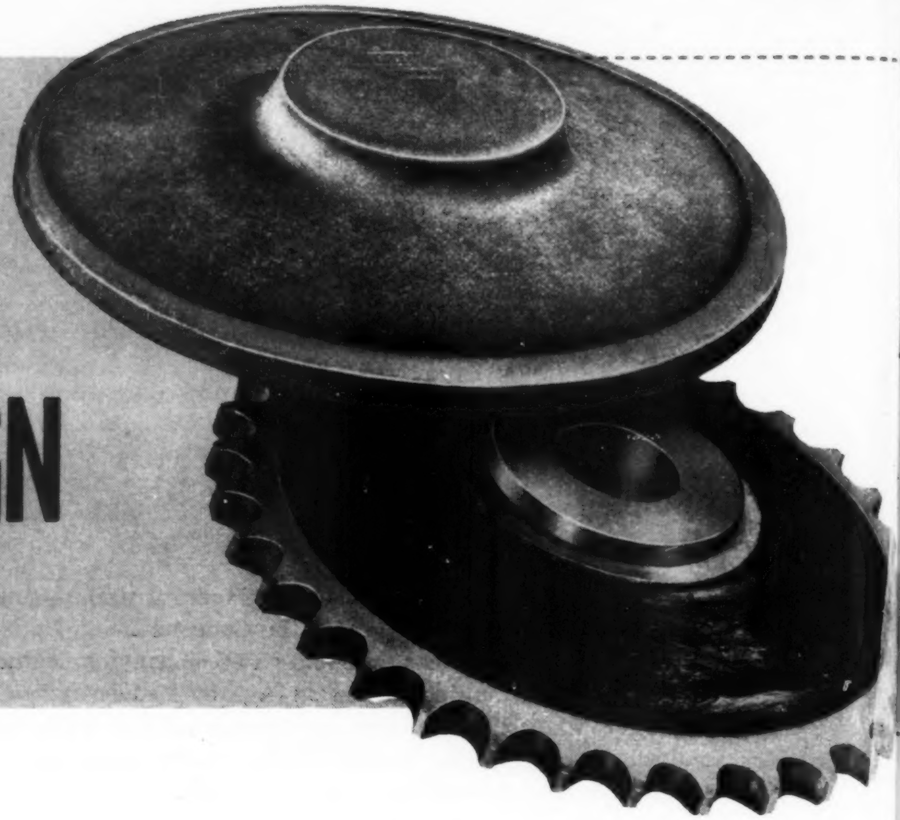
We fully recognize the criticisms of those who object to the fact that not all our pages are easy reading. But unless we challenge the intellect of our readers we lose the right to call ourselves a professional journal and we cannot expect to retain our editorial leadership in the design engineering field. While giving full attention to the real and important needs of our mass readership, we intend to continue to "reserve a place for uncommon excellence . . . and emphasize the highest rather than the lowest common denominator."

Colin Carmichael

EDITOR

Evaluating

CAST DESIGN



EVALUATING designs for producibility and proving designs prior to release for production obtains the best possible machine components at the lowest possible cost. Regardless of method, this precept holds true; and with foundry processes may even be imperative for best results. In this article a method of casting development that unites good structural design and good foundry practice, and has been proved highly satisfactory, will be outlined.

Analysis of Design: The design engineer should carefully consider the following points when designing a new component, or redesigning a part for casting.

Why Cast It? When considering this question it is well to keep in mind the numerous advantages of the casting process. Perhaps the most important of these is that the process in itself is the most direct method of producing either intricate or simple parts. The wide range of mechanical properties possible is another; and, of course, there are many more reasons for arriving at an affirmative answer. This question stimulates the thinking of all concerned; and once the decision is made, the efforts of everyone involved will be directed toward the objective—a good casting design.

What Is the Quantity Involved? This will determine the extent to which the part should be developed and how.

Is Time Available for Development? The size and nature of the part will determine the amount of time required. It should be stressed that this method requires less time and proves the design before releasing for production, whereas the accepted method releases largely unproved designs, or designs entirely dependent on sometimes questionable mathematical calculations, for production and results in costly errors.

What effect will the design have on the part functionally, structurally, and will it be compatible with good foundry practice? In short, the part must function properly and carry the service loads. The general shape of the design is determined at this point; and many provisions can be designed into the part so that an economical operation for the foundry will result, *Fig.* 1.

Will the Weight be Satisfactory? Weight is as important as maximum strength and minimum weight is always desirable. Also weight is one of the big factors in determining the price of the casting.

Is Cost a Factor? It invariably is. Minimum cost is obtained when the part is properly designed as the casting can be produced more economically. The casting design should be based on facts and not opinions.

Method of Product Design: After considering these questions and an analysis of the desired product has been made, the design engineer is acquainted with the facts of his problem and is now in a position to develop the design of the part. The first step is to produce free-hand sketches of the proposed design.

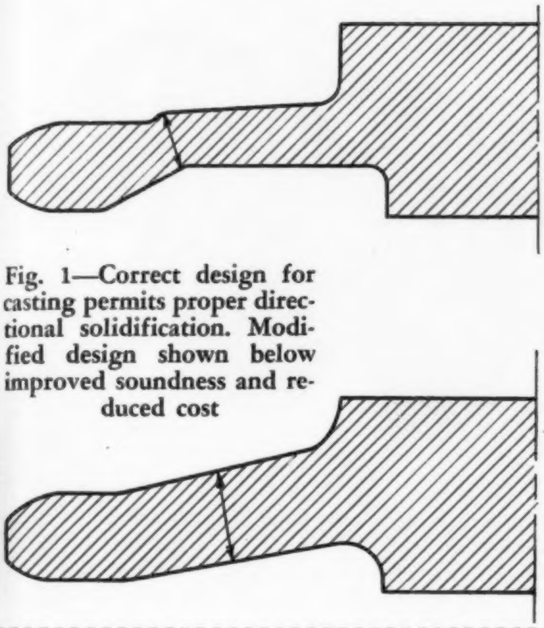


Fig. 1—Correct design for casting permits proper directional solidification. Modified design shown below improved soundness and reduced cost

Economical production and full utilization of the inherent advantages of castings for critical components can be secured by systematic design procedures. One practical approach is outlined by the author

By Robert J. Franck
Superior Steel & Malleable Castings Co.
Benton Harbor, Mich.
Development Engineer

Sketches provide freedom of design not found on the drawing board. Sections can be blended and proportions changed more readily because thought processes are not disrupted by technical details of engineering drawing.

While the general shape of the casting is defined by these sketches, the designer's ideas are solidified for the first time in a mock-up, *Fig.* 2. The basic materials for mock-ups are wood, plastic, clay, plaster and wax. These materials are readily formed to the desired shape and changes can be made with ease. Quite frequently, a mock-up can be used as an experimental pattern. Therefore, they should be made to actual size or to scale if the part is large. The mock-up brings into being the desired structure and is readily understood by every one concerned.

At this stage, consultation with the foundry engineer will aid in determining how the pattern should be laid out, and how the foundry can best cast the part, as well as suitable gate and riser systems. During such consultation, it becomes apparent to

Fig. 2—Typical casting mock-up for development of a crankshaft throw

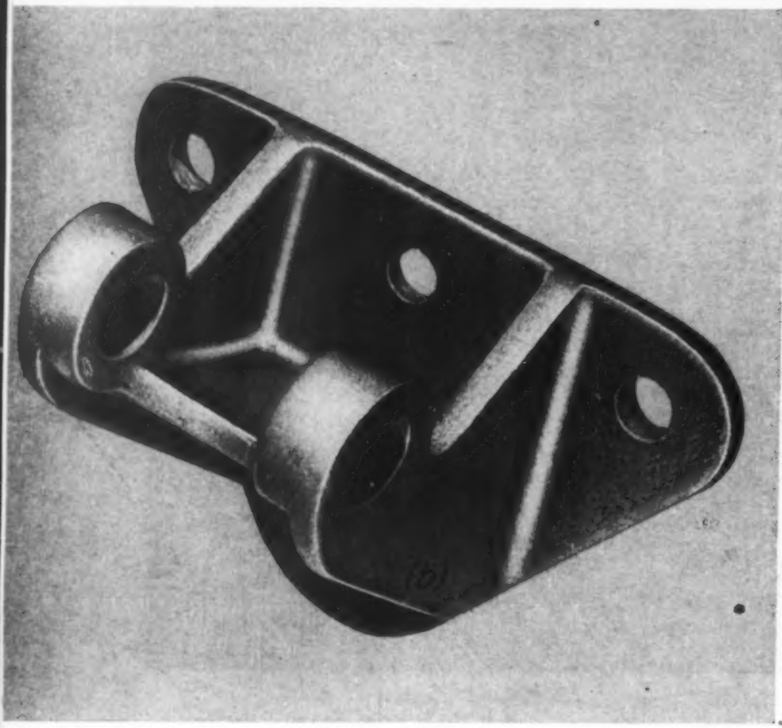


Fig. 3—Original cast steel hinge bracket design, *a*, and redesign *b*, which eliminated two cores, made cores for hinge pin and main base integral for alignment, and improved stress conditions

the design engineer what effect his proposed design has on the foundry procedure. The foundry engineer can point out ways of improving the proposed design in order to utilize the advantages of the casting process. It is a distinct advantage to have freehand sketches and mockups made at this point as suggestions can be made readily understandable by either sketching or adding or taking away clay on the mock-up. These suggestions, incorporated into the design wherever possible, create the point of union between design and good foundry practice.

In *Fig.* 3 is illustrated how the proposed design was modified by placing the bosses on the inside, resulting in the elimination of two cores. The cores for the hinge pin and main base were made integral, thereby insuring their being in alignment with one another and parallel with the base. All ribs were placed in such a position that they formed a single component which was under direct compressive stress. A reduction in weight of 3.4 pounds was made and the total cost of the bracket was reduced 15.9 per cent.

At the conclusion of the consultation with the foundry, a written report covering equipment required, cost of sample casting, cost of experimental stress analysis, nature of test, and outlining general procedure is in order. This will serve as a guide and co-ordinate the efforts of the design engineer and the foundry engineer. Included in this report should be an estimated selling price. However, it should be pointed out that the results of tests may alter a proposed design and affect the final selling price.

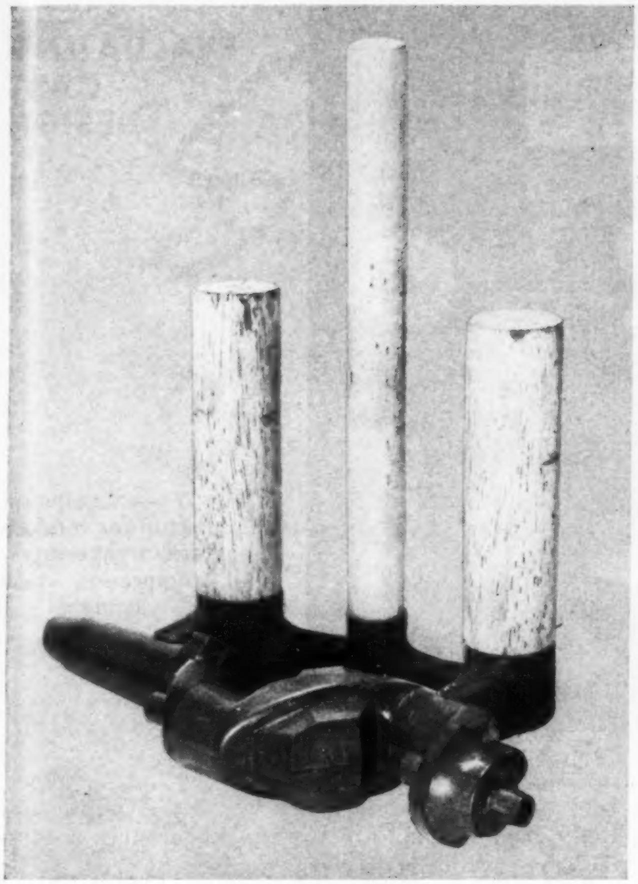
Production of Sample Castings: Experimental castings can be made by the foundry from either the mock-ups or inexpensive patterns. In some cases the master patterns can be made and used for production of experimental castings, if the double shrinkage does not have an effect on the final dimensions of the casting. This saves both time and money later on. Wood gates and risers should be attached to the experimental patterns. In this manner, the foundry engineer can establish control over production of experimental castings and eliminate guesswork in this vital phase, *Fig.* 4.

To provide factual data as to any adverse effects the proposed design has on the molding process, close engineering follow-up is necessary by the foundry. Changes in design may be possible that would improve molding with production pattern equipment.

Experimental castings are checked for visual and hidden defects, dimensions, gross weight and net weight The castings are then machined and assembled. This close follow-up of the experimental castings is necessary as knowledge is gained which is pertinent to the final design of the part.

Evaluating the Design: At this stage the casting is ready for design evaluation by experimental stress analysis. This can be done by testing the part in its own environment or under simulated conditions. Brittle lacquer and strain gages are excellent methods of evaluating the design quantitatively and qualitatively. These useful tools permit the engineer to determine accurately the functional characteristics of a particular design.

To accomplish this the engineer requires a stress analysis laboratory with the proper equipment—or one that is available to him. The laboratory requires two rooms, each of appropriate size depending on the size of work to be analyzed. One room is equipped with a brittle lacquer outfit—spray booth with blower system—and is used for the preparation of a specimen, *Fig.* 5. The other room is used for testing. Basic equipment is a heavy steel testing



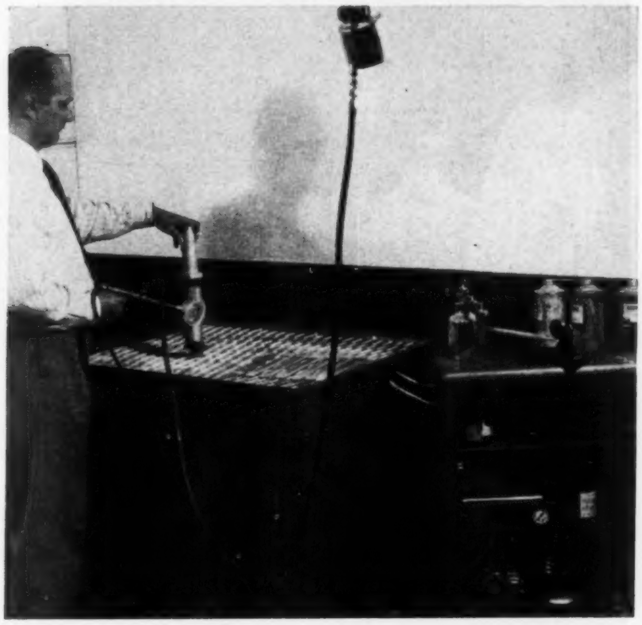


Fig. 5—Above—Applying Stresscoat in the laboratory preparation room

Fig. 6—Below—Test crankshaft showing areas of high stress indicated by the brittle lacquer coat

Fig. 4 — Above — Crankshaft master pattern with wood gates and risers attached for production of sample casting

table, hydraulic jacks and an air-conditioning unit. Stresscoat is a commercially available brittle lacquer and can be used without controlling temperature and humidity. However, an air conditioning unit will enhance the results.

The surface of the casting to be tested must be absolutely clean and free of loose scale, grease and paint. The strain indicating coating is selected for the conditions that will prevail at time of test. The coating is then sprayed on the casting uniformly and at the same time the calibration strips are coated. The part is assembled into the test setup and allowed to dry at 90 degrees or more for twelve hours in the testing room. The air in the room is brought under control to conform to the conditions for the selected coating.

Calibration of the coating is then made by applying a known strain to the strips and the strips are then placed in the strain indicating scale where the coating sensitivity value is read. Loads simulating those which will be encountered under actual service conditions are then applied to the casting. Cracking of the brittle coating forms fine hair-like patterns at right angles to the maximum principal tensile

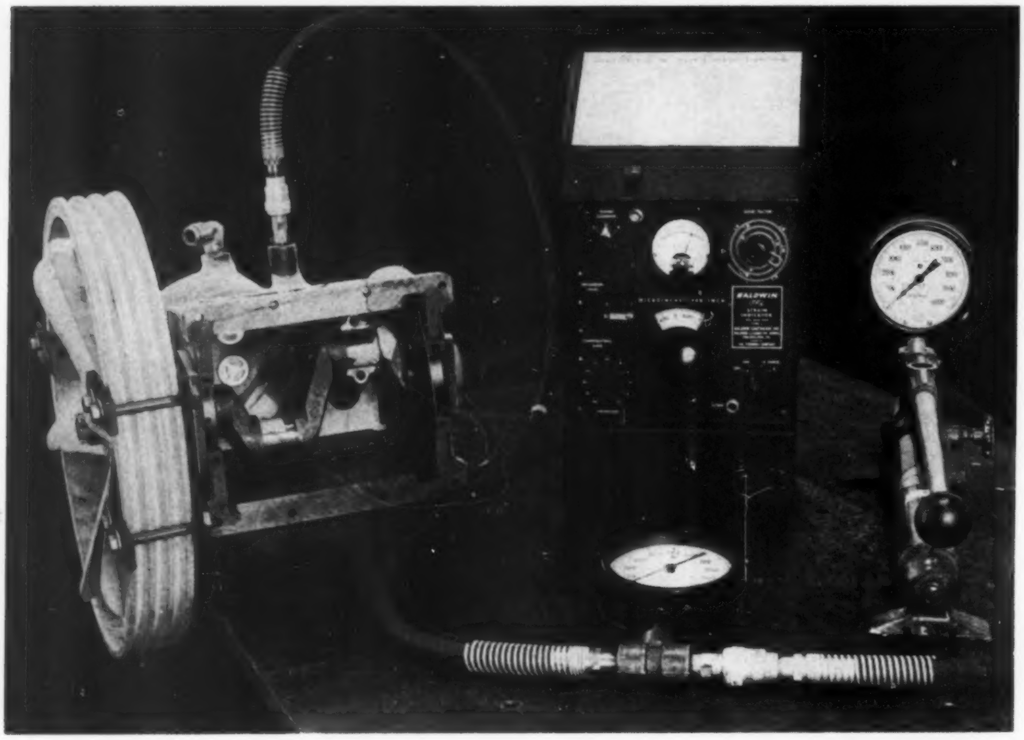


Fig. 7 — Equipment and setup for conducting strain gage survey of compressor crank casting

strain, *Fig.* 6.

For accurate quantitative values, detecting the formation of the first strain pattern in the coating and calibration of the coating at the time of testing is important. The strain pattern, or patterns formed on the casting are then matched with the known patterns on the calibration strip and values read from the strain scale. Apparent values of stress are then computed by multiplying the value of strain by the tension modulus of elasticity of the casting.

Stress may be computed from the strain lines with an accuracy of about 15 per cent. However, Stresscoat clearly indicates the location and orientation points for resistance wire strain gages which have an accuracy of 2 per cent. When actual quantitative information is required, Stresscoat analysis is essential but should be followed by a strain gage survey, *Fig.* 7.

Modification of New Design: General stress distribution patterns give an overall picture of service stress conditions and possible improvement in the design of a structure usually becomes apparent. Strain gage results prove whether the design of the part is adequate to carry the loads and assure the design engineer that a proposed design will meet service requirements. If not, the results of the experimental stress analysis will indicate the action necessary to improve the stress distribution. This is done by adding or removing metal adjacent to the highly stressed areas. When modifications in the design have been effected, the test procedure is repeated. Thus, optimum designs may be developed based on facts instead of opinions. Modifications are made and evaluated by stress analysis until the design is acceptable.

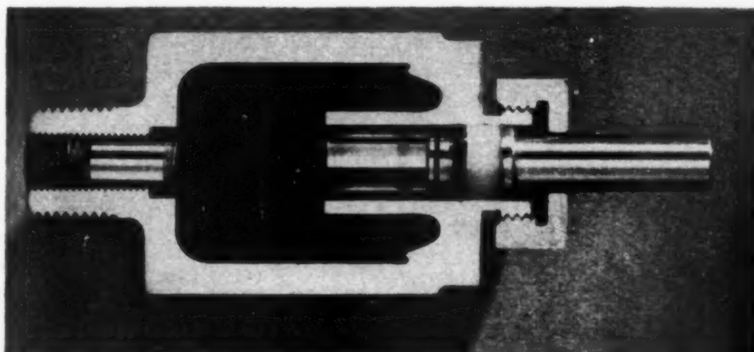
Conclusion: As a rule, correct basic design can be developed directly through this procedure and only slight modifications are required to produce a satisfactory part. The design engineer by this simple means acquires all the facts pertinent to the design of a part. With tests completed, he is in a position to make all necessary engineering drawings and write the final report with full knowledge that he has a proved design engineered for economical production. The release for production can be written with complete confidence as the casting design has been based on sound engineering principles—engineered for the foundry—with the foundry.

Bottling Machine Serves 30 Years

A BOTTLE-FILLING machine which refuses to wear out is still in use at the Minneapolis plant of Canada Dry after serving for over 30 years there and in two other bottling plants. In first-class operating condition, the machine has outlasted three amortization schedules and is now working at 110 per cent of rated capacity. Total output thus far is calculated at slightly over 400 million bottles—2½ bottles for every person in the United States. The company's explanation for this endurance record is that the machine was well engineered to begin with and has received careful maintenance.

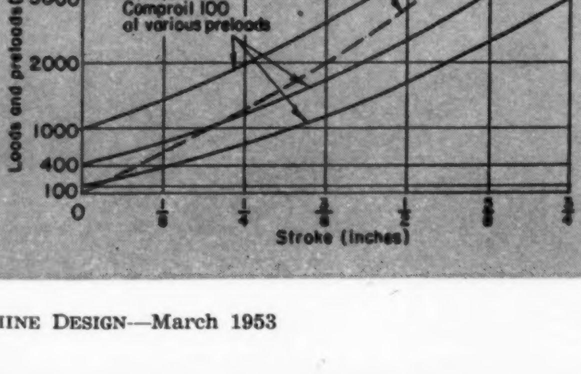
" 'Thrust' is a word that has become familiar to all of us since the advent of the jet era. But I think that thrust has a production concept also. It is the driving force that gets a job done despite all obstacles. and pushes irresistibly toward the single, vital goal."
—E. W. Rawlings, *lieutenant general, U. S. Air Force*

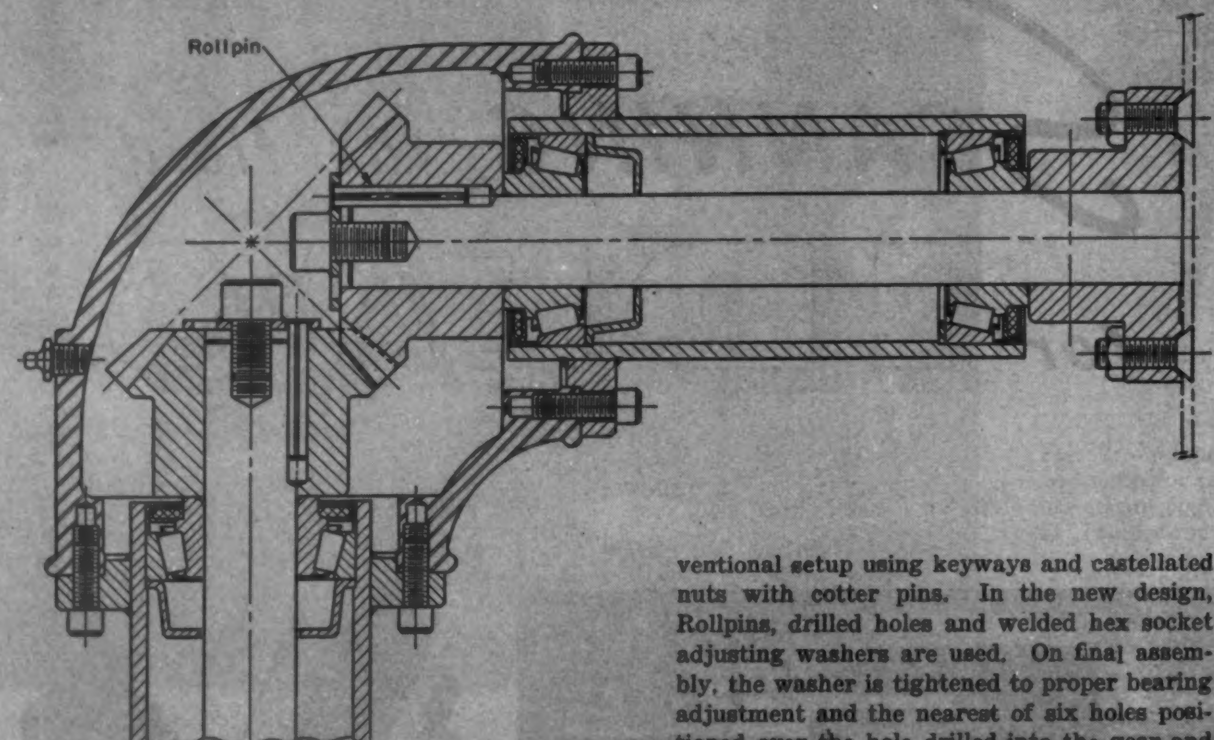
Scanning the field for IDEAS



Liquid springs offer high recoil power in minimum space without problems of permanent set. The Hydra Spring, developed by the Wales-Strippit Corp., utilizes various specially compounded compressible oils to achieve the same resilient action provided by conventional springs. Designed in several styles of stroke and preload, these cylindrical units will develop a recoil force as high as 3800 pounds, six to ten times the springing force of a coil spring of equal size and volume.

Unlike mechanical springs, the force of Hydra Springs may be varied by changing the special oils or the volume utilized. One oil offers 6.2 and another 10 per cent compression at maximum load. Limited variation in preload is accomplished by setscrew adjustment of the small force adjuster piston. Typical spring characteristics are shown by the graph. Strokes range up to 1½ inches, maximum.

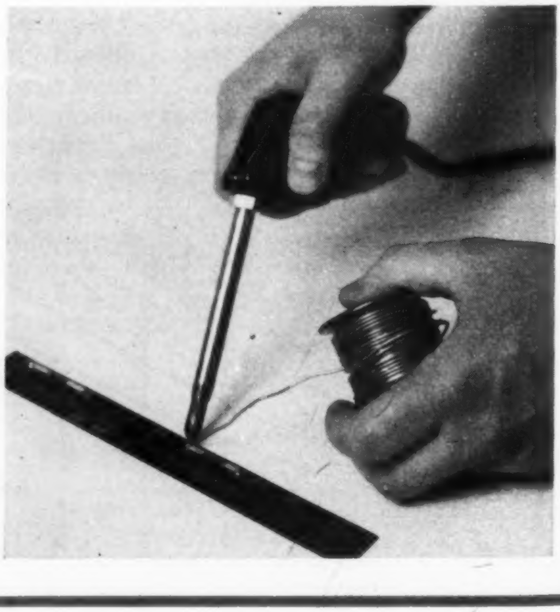




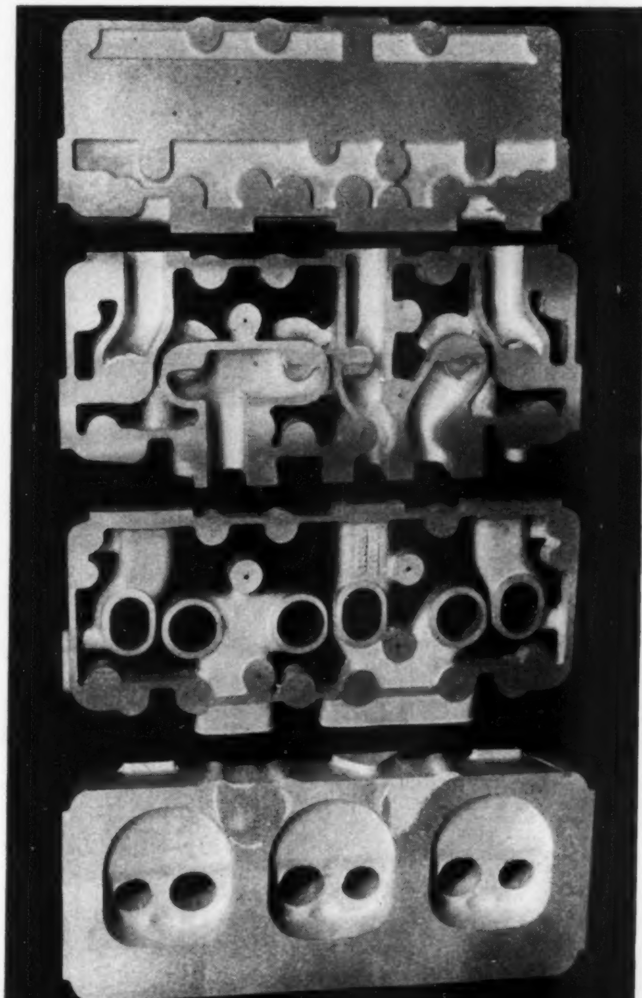
Spring-pin locking of bevel gears simplifies installation and facilitates adjustment of the taper roller bearings. Developed by Belsaw Machinery Co. for a tubular power saw drive, the design makes possible a 60 per cent saving in production time and replaces a conventional setup using keyways and castellated nuts with cotter pins. In the new design, Rollpins, drilled holes and welded hex socket adjusting washers are used. On final assembly, the washer is tightened to proper bearing adjustment and the nearest of six holes positioned over the hole drilled into the gear and shaft. The slotted tubular Rollpin, oversize with relation to the hole, is driven in flush with the washer.

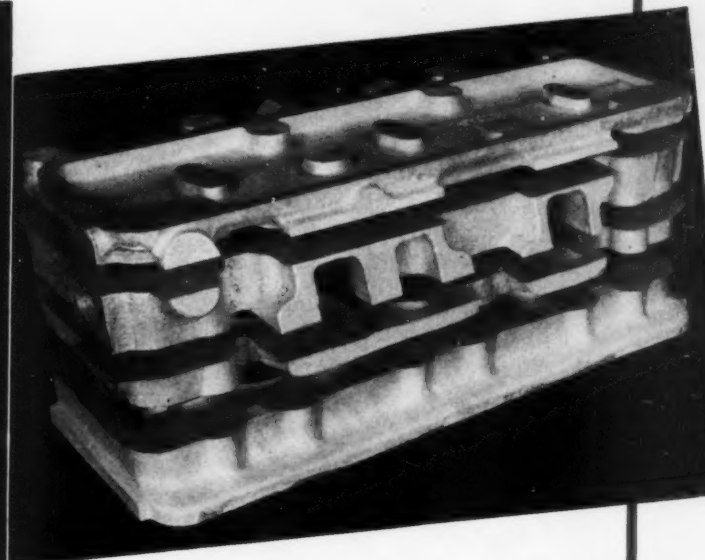
Constant spring force of the tubular pin assures secure retention of adjustment. For gear removal or bearing adjustment, the pin need only be driven tc full hole depth so that the washer can be removed. The pin drops out as the gear is removed.

Tape resistors, designed for electronic printed-circuit applications by the National Bureau of Standards, need no heat curing as did previous types. Precured and bonded to silver or silver-plated copper leads, the resistors may be soldered or spotwelded into the circuit conventionally. Compactness, stability and high-temperature operation are characteristic advantages of the units which measure about ⅛-inch wide by 1½ inches long by 0.012 to 0.015-inch thick.



IDEAS





BUILT-UP CAST DESIGN in the form of "slices" simplifies the casting process and eliminates coring problems. Brazing offers the ideal method of assembling the slices. By dividing aluminum castings into simple easy-to-make sections, both high-production and quality can be achieved. Developed by the Aluminum Company of America, brazed designs using permanent-mold cast C612 aluminum alloy segments for engine blocks—a really complex casting—have been successfully produced. Actual engine operation shows no structural difficulties.

Unique possibilities in cast design are evident and further, the brazing of the aluminum segments can be done satisfactorily with as-cast flat faces commercially possible with permanent-mold castings. The C612 alloy has excellent elongation and where necessary, coining or disk or belt grinding can be utilized. Depending on the type of joint, No. 718 brazing medium in the form of sheet or wire is used and brazing carried out with No. 33 flux at 1085 F. Liner tubes of iron and 61S alloy have also been brazed-in satisfactorily.

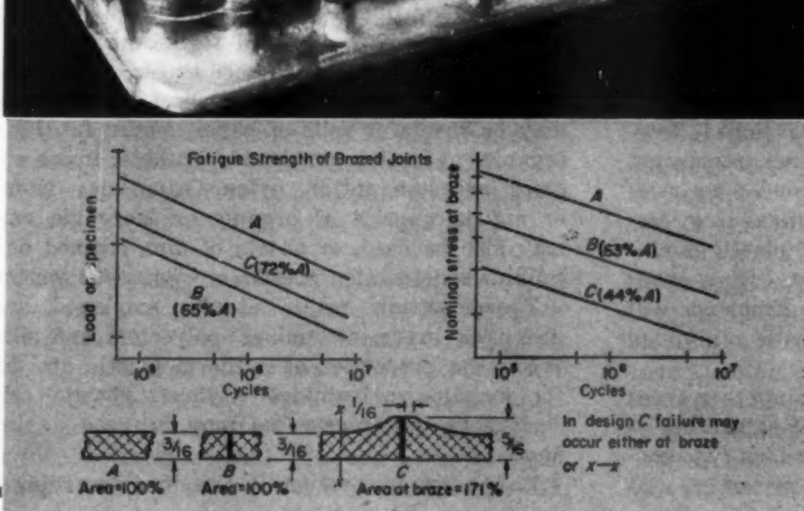
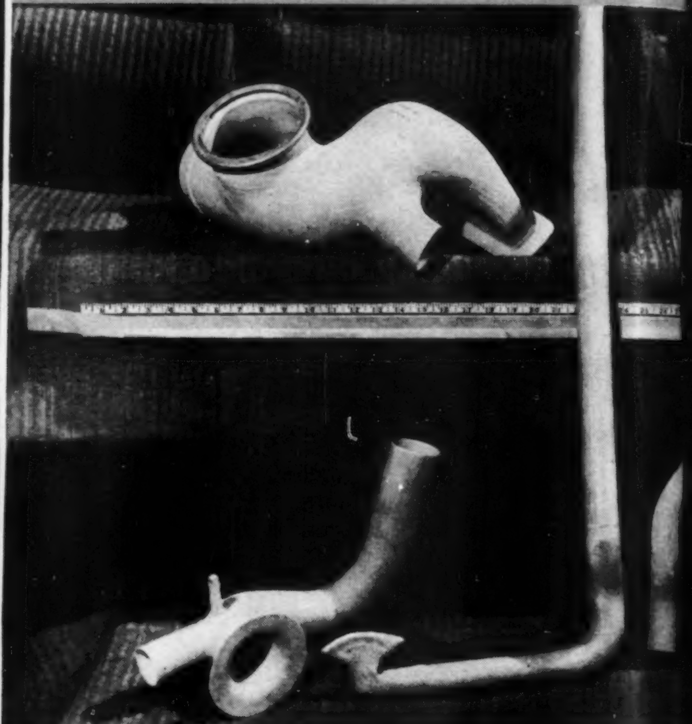


Fig. 1—Low-pressure laminated fairing houses a warning light system installed on the rear belly of the KC-97 which directs the pilot of the aircraft being refueled

Fig. 2—Complicated ducts are typical of components which can be fabricated by glass fabric-reinforced plastic lamination



Low-P

By Robert King
Engineering Process Unit
Boeing Airplane Co.
Seattle, Wash.

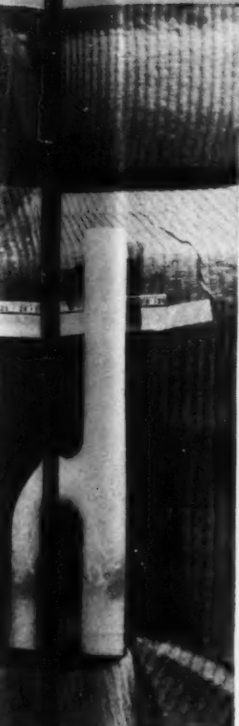
PRIOR to World War II, available forms of plastic laminates were largely restricted to simple structures, such as sheets, tubing and rods molded at high pressures. With the advent of the war, a new family of low-pressure laminates was developed—low-pressure thermosetting alkyd resins of the unsaturated polyester type. Capable of being produced by relatively simple manufacturing methods, these new laminates made possible the production of plastic laminates in relatively large, complex shapes, *Fig.* 1, opening new areas of use for the designer. Emphasis will be placed on the use of alkyd-resin plastic reinforced with various glass-fiber fabrics.

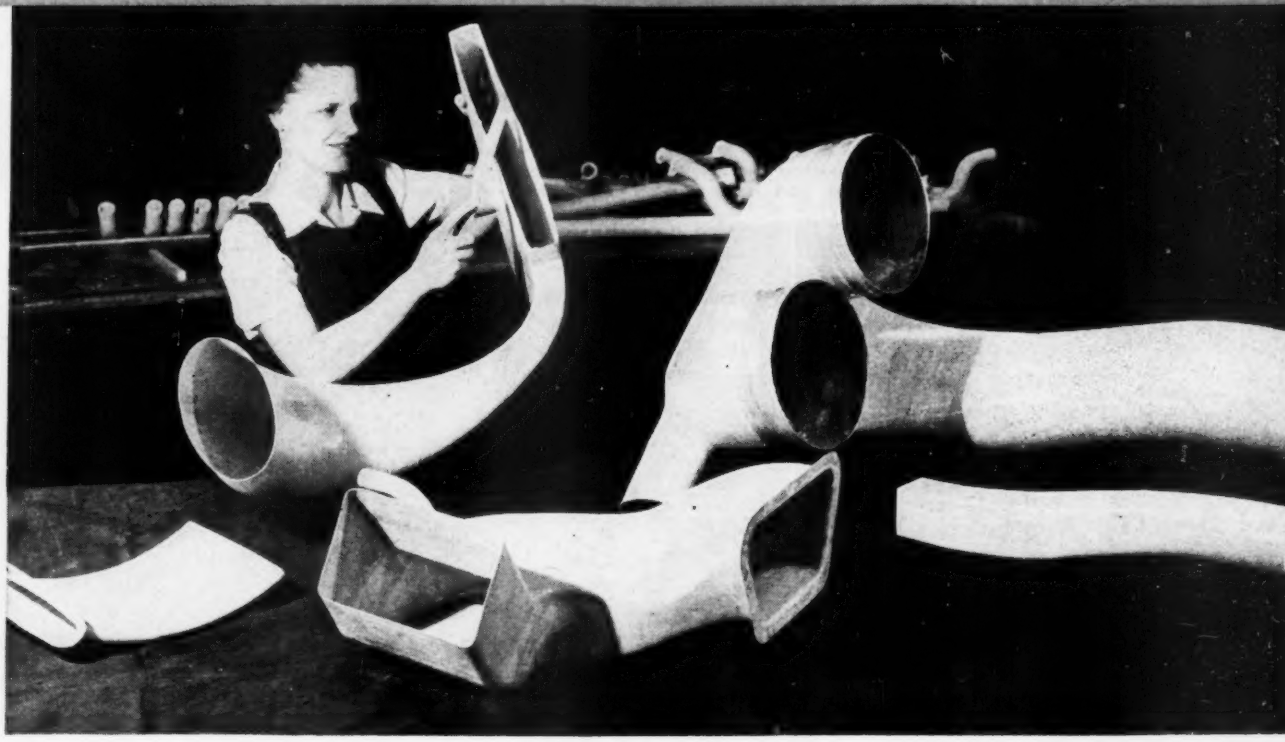
Plastic laminates, as distinguished from other types of fiber-filled plastics, are made by (1) saturating or impregnating layers of a filler of continuous-type construction with one or more resinous materials, (2) "laying up" or laminating the plies of the impregnated filler to achieve the desired form, and (3) applying pressure and heat to compact the laminate and cure the impregnant, usually a thermosetting resin. Fillers may be sheets or rolls of paper, woven fabrics of inorganic, natural organic and synthetic fibers such as glass, asbestos, cotton, nylon, Orlon, etc. Nonwoven or matted fabrics of organic or inorganic varieties may also be used, or sheets of film, foamed or other cellular construction plastic, or even wood veneers.

Thermosetting resins usually employed are the phenolics, ureas, melamines, polyesters and silicones. When the properties of a thermoplastic are desired, the acrylics, polyamides (nylon), certain cellulose derivatives or polystyrene may be used as impregnants.

Laminates are frequently classified according to the

Fig. 3 — Large or small cross sections, and parts with re-entrant areas, may all be fabricated by low-pressure lamination





-Pressure Laminates

Offering almost unlimited versatility in the design of large or complex shapes, glass fabric-plastic laminates are produced by a simple manufacturing process, relatively inexpensive in small quantities

pressures employed in their fabrication: high-pressure laminates are those fabricated at pressures of from 1000 to 2000 psi; low-pressure laminating employs pressures below 200 psi; those low-pressure laminates fabricated at pressures of from 0 to 10 psi are usually called contact laminates. This classification is only general in nature, and certain materials and processes may be used for one or more types of laminates.

Materials: Polyester resin products reinforced with glass fiber are analogous to reinforced concrete; each group of glass filaments (average tensile strengths of 270,000 psi) acts as a reinforcing rod when supported and given "body" by the resin. Unsaturated polyesters are generally highly viscous liquids which polymerize (change from a liquid to a solid form by great increases in the length, branching, and molecular weight of the resin chain) upon the addition of certain oxygen-containing catalysts (peroxides) and the application of heat (70 to 250 F). Commercial laminating resins are modified by the addition of liquid hydrocarbons such as styrene which lower the viscosity and aid the cross-linking or branching of the polyester during polymerization, resulting in a three-dimensional molecular structure.

It is this three-dimensional structure which lends thermosetting properties and increased solvent resistance—as compared with thermoplastics—to polyester resins. In comparison, thermoplastics, which soften upon heating and can be remelted, have relatively straight-chain polymers which slide upon each other upon application of heat.

Glass fabrics for plastics reinforcement are woven by various commercial mills from glass-fiber yarns,

PREPARING THE PLASTER MANDREL

a. Low-viscosity molding plaster is poured into three-piece air-duct mold—itself of laminated glass-fabric construction

b. Excess sloshing plaster is then poured out from the mold

c. After hardening, the plaster mandrel is removed from the mold and dried

d. The plaster mandrel then receives a coating of a parting agent. The part is an aircraft alcohol-water injection tank


(a)


(b)


(c)

LAYING UP THE LAMINATE

e. Glass fabric is impregnated with a polyester-resin plastic in a knifecoater. White color results from the addition of antimony oxide, a fire retardent

f. Stacked piles of impregnated glass fabric are cut according to prepared patterns

g. The laminate is then "laid up"—each ply of fabric is tailored and positioned on the mandrel

h. Low-density foam cores (cellular cellulose acetate) may be added to provide greatly increased stiffness


(e)


(f)


(g)

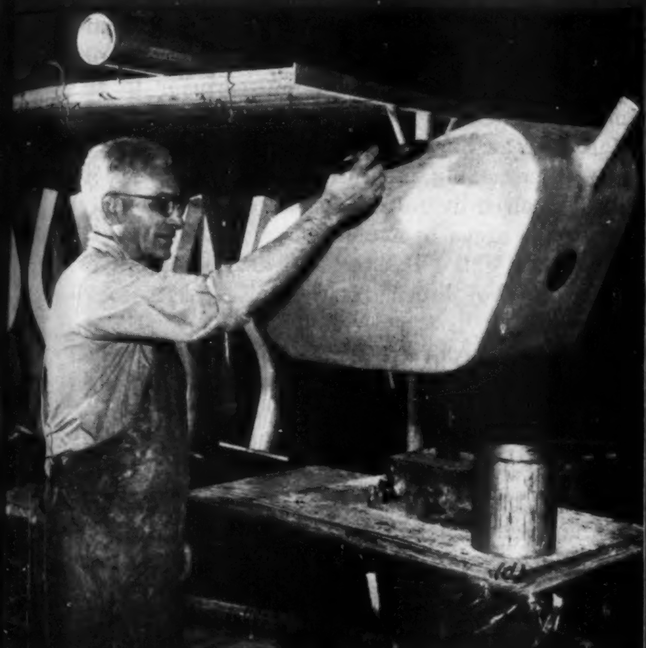
MOLDING THE LAMINATED PART


(i)


(j)

i. The layed-up laminate is enclosed in a vacuum bag of polyvinyl-alcohol film, after which the laminate is cured under vacuum of 20-24 inches of mercury at 200-250 F

j. After curing, the plaster mandrel is broken out of the laminated part with rubber paddles



k. Remnants of plaster and the parting agent are removed by soaking. In a newer process for removal, a special plaster is merely soaked in warm water

l. Some components are given an additional sealing coat of polyester resin by filling and applying pressure, forcing the resin into any voids or leaks

Fig. 4—Manufacturing procedure for plastic-impregnated glass-cloth parts, custom-laminated by bag-molding

made in turn from filaments of low alkaline-content glass to facilitate "wetting" of the fibers by the plastic. The weaving, using conventional equipment, requires that the glass threads be lubricated to avoid self-abrasion with consequent breakage and lower strength. After weaving, the lubrication is removed and the fabric given certain surface treatments to effect the production of laminates having maximum wet and dry strengths. In the laminate the surface treatment acts as an intermediate bond between the impregnating resin and the glass fibers.

Types of Laminates: Low-pressure laminates include standard commercial laminates manufactured by "outside" companies and those custom-made laminated products (usually contoured) made in accordance with the custom-molding techniques outlined herein, *Fig.* 2. Some of the available varieties of laminates are outlined in TABLE 1.

One interesting application of low-pressure laminates is the mocking-up of complex skins, fairings, etc., using inexpensive Osnaberg cloth, a moderately-loose weave cotton fabric, as the reinforcement in place of the glass fabrics.

Manufacturing Method: The various types of low-pressure laminates differ markedly with respect to the manufacturing process employed and to the type and cost of tooling required for production. Standard commercial low-pressure laminated sheets, as shown in TABLE 1, represent but one phase of low-pressure laminating. These are produced by the continuous-

Table 1—Typical Plastic and Glass-Cloth Laminates

Classification	Uses	Remarks
Custom-molded		
Nonstructural	Covers, junction boxes, housings; contoured parts with no electrical requirements.	Can be flameproofed with some drop in strength.
Nonstructural	Ducts for heating, deicing, etc.	All parts flameproofed.
Structural	Exterior laminates, antenna housings, isolating sections, fin tips, cavity antennas.	For laminates with critical electrical requirements; complies with USAF 12051.
Structural	Radomes, antennas.	Honeycomb sandwich structure; USAF 12053.
Standard*		
Nonstructural	Casings for support and prevention of chafing of fuel cells.	Flat panels; semiunidirectional strength.
Nonstructural	Parts with simple curvature, cargo liners, D-section ducts.	Bidirectional-strength panels; several grades with various impact strengths.
Nonstructural	Backing boards for self-sealing fuel tanks.	Do not flower inward on impact from projectiles; two types, intermittently or continuously supported.

* For products involving only flat or simply curved sheets.

contact process. Continuous-contact laminates include the vast quantities of decorative laminates used for the surfacing of bars, dinette tables, kitchen cabinet counter tops and similar applications; the vast majority of these are paper-base laminates, as compared with the glass-fabric base laminates discussed in this article. Special blotter-like, unfilled white papers make up the bulk of the laminate while the surface ply (or plies if both sides of the laminated sheet are to be decorative) is a firmer, less porous paper upon which the desired design and color are printed.

Custom low-pressure laminating of nonstructural products, *Fig.* 3, differs in that each part is prepared separately upon a form or mandrel, usually of contoured configuration, which may or may not be expendable. For a typical part (a junction box, for example) a plaster mandrel is prepared to the inside dimensions of the desired part, *Fig.* 4. After oven-drying to remove the free moisture, the plaster is brush or spray-coated successively with (1) a special parting lacquer and (2) an aqueous solution of polyvinyl alcohol. Upon drying the resultant film does not inhibit the curing of nor adhere to, the polyester laminate.

Glass fabric, impregnated with the plastic is "laid up" on the prepared mandrel; each ply is usually tailored to the contour of the mandrel prior to the addition of the next ply. Strength is maintained in the tailored areas by lapping the cut edges from ½ to 1 inch. Succeeding plies, in number sufficient to achieve the desired overall thickness, are tailored and lapped in other areas to avoid excessive thickness increases. Where extra thickness is desired, however, additional pieces of fabric may be inserted in localized areas.

The layup—still on its plaster mandrel—is then "bagged", i.e., is placed in a bag of transparent film which is then connected to a source of vacuum pressure and evacuated of air as in *Fig. 3i*. Curing of the impregnant is accomplished by placing the assembly in an oven at 200-250 F for two to six hours depending upon laminate thickness and mass of the plaster mandrel. Vacuum pressure is maintained during the curing cycle.

To minimize warpage, the part is allowed to cool prior to the removal of the plaster mandrel—usually effected by breaking up the mandrel with rubber mallets. Permanent or semipermanent mandrels of aluminum, Kirksite, steel or wood may be utilized for the laminating of components having no re-entrant areas (undercuts) which are required in larger quantities.

Certain structural laminates are manufactured by procedures similar to those just described, with several important differences:

1. Shapes are generally flat or slightly contoured although simple, "open" structures may be thus fabricated.
2. Permanent mandrels with highly polished molding surfaces are usually employed.
3. Complete impregnation of the fabric is usually accomplished after the bagging of the fabric lay-

Table 2—Physical Properties of Typical Light Construction Materials

Property	Structural Glass-Fiber Plastic Laminate	Aluminum Sheet (24S-T4, clad)	Magnesium Sheet (FS-1A)	Laminated Phenolic Sheet (Type II, Grade C)*
Ultimate tensile strength (psi)	38,000	61,000	32,000	7,500
Yield strength (psi)	.....	38,000	15,000	.....
Specific tensile strength (psi)†	21,300	13,700§	8,450§	5,500
Compressive strength (psi)..	21,000‡,**	38,000§	13,000§	35,000
Spec. compressive strength (psi)†	11,800‡	13,700§	7,350§	25,700
Flexural strength (psi)	45,000**	.....	.....	16,000
Spec. flexural strength (psi)†	25,300	.....	.....	11,750
Modulus of elasticity, flexural (psi)	2.5×10^{6}**	10.5×10^{6}	.....	.....
Specific gravity at 70 F.....	1.78	2.77	1.77	1.35
Density (lb/cu in.)	0.064	0.100	0.064	0.049
Flame proof	Yes	Yes	Yes	No
Fireproof	No	Yes	No	No
Thermal conductivity (Btu/hr/sq ft/in./deg F) ..	3	1400	1100	1.5
Thermal coefficient of expansion, linear (per deg F)...	10×10^{-6}	12.5×10^{-6}	14.5×10^{-6}	12×10^{-6}

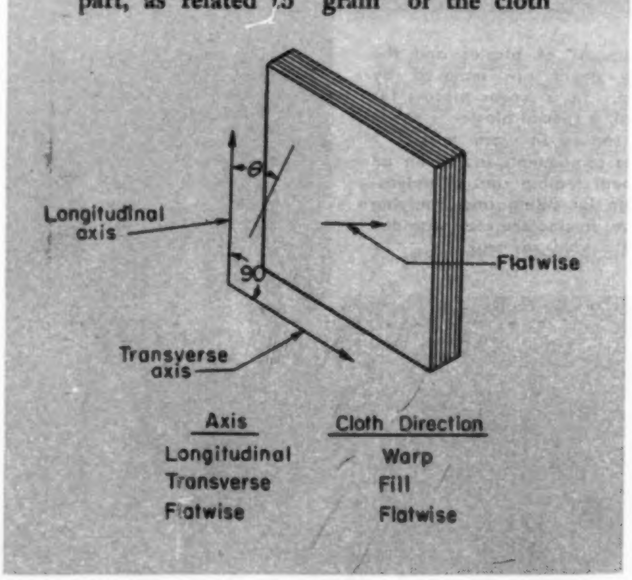
*,** Minimum ultimate strengths allowed under Federal Specification HH-P-256 or USAF Specification 12051, respectively. †Strength-weight ratios—unit strength divided by specific gravity. §Figures are, or are based on, yield values. ‡Values are edgewise compressive strengths.

Table 3—Percentage Retention of Dry Strength After Exposure to Moisture

Loading	Exposure	Temperature	Strength Retention (per cent)
Tensile	24-hr immersion	Room	96.4*
	2 months, 100% RH	100 F	88.0†
Compressive	24-hr immersion	Room	91.4*
	2 months, 100% RH	100 F	64.0†
Flexural	24-hr immersion	Room	94.4*
	30-day immersion	Room	69.7*
	70-day immersion	Room	74.5§
	70 days, 100% RH	75 F	72.4§
	70 days, 100% RH	100 F	70.9§

*Boeing Aircraft Co. Test Report T-27950. †Forest Products Laboratory Report 1820, February 1951. †Forest Products Laboratory Report 1819, October, 1950.

Fig. 5—Axis designation for the laminated part, as related to "grain" of the cloth



up. Portions of the total amount of resin calculated to accomplish the impregnation are poured between each ply, the vacuum bag sealed and evacuated, and the resin is drawn through the dry fabric, flushing the residual air in front of it. Thus, aided by the adroit use of squeegee-like paddles, a "void-free" laminate is attained.

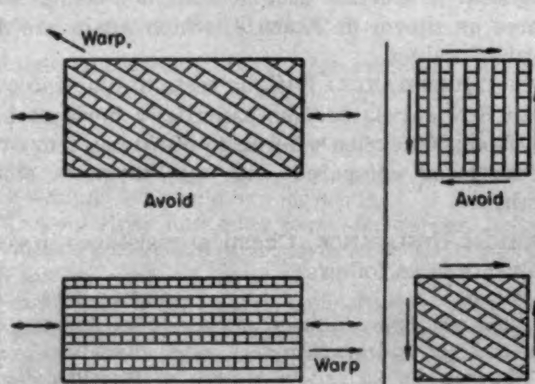
4. Curing temperatures of about 250 F, which may have been preceded by gelation at room temperature, are employed to achieve the required structural strength.

Structural Properties: Plastic laminates have excellent structural properties, as shown in TABLE 2. Comparison of plastic laminates with structural metals, however, reveals the laminate as being a nonhomogeneous, anisotropic material; i.e., the laminated material does not have the same properties at every point, and its elastic properties will depend on the direction of application of the load. Laminates composed of many thin plies regularly arranged may be considered homogeneous, however, for purposes of structural calculations.

Since laminates are anisotropic material, any statement of the physical properties of a laminate must also specify the direction of loading during testing. One of the systems employed to designate the directions in any laminate and its relationship to the "grain" of the reinforcing cloth is shown in *Fig.* 5. In conjunction with these designations, the terms "parallel laminated" and "cross-laminated" are employed to designate regular arrangements of the reinforcing fabric with all of the warp threads parallel to the longitudinal axis, or warp threads of successive plies rotated 90 degrees from each other, respectively.

Design of glass laminates should take cognizance of the anisotropic nature of the material and endeavor to align all or most of the warp threads with the direction of the loading, *Fig.* 6. This may not be possible with all designs, since utilization of the relatively unlimited length of warp threads may be advantageous to eliminate presence of laps, even though greater loads might then fall upon the fill threads. In such an application a bidirectional cloth (one having equal or nearly equal strengths in both the warp and the fill threads) should be employed. Unidirectional cloths, on the other hand, may be advised when the loading is predominantly in one direction. The anisotropic nature of glass fabric-reinforced laminates is illustrated in the directional graphs of *Fig.* 7. The nonhomogeneous nature of the material should also be considered in laminate design, as shown in *Fig.* 8.

Fig. 6—In designing laminated parts, warp threads should be aligned with the direction of loading



Choice of the fabric reinforcement has considerable bearing upon the properties of the laminate. In addition to the directional nature of certain cloths, ply thickness and type of weave may determine the suitability of a given reinforcement for a certain application. In general, for a given thickness of product, higher strengths are realized when using the greatest number of laminae, i.e., the smallest thickness per ply; this is especially true of the compressive strength. An important exception is flatwise impact strength, which increases with greater thickness of each ply because of the greater degree of crimping in the fibers. Upon impact, the crimping is straightened out and in so doing absorbs the load with a minimum tendency to break the fibers.

Types of weaves of glass fabrics designed for plastics reinforcing may be broadly classified as shown in *Fig.* 9. Of the three types, the long-shaft satin weaves are generally the most satisfactory reinforcements; substantially higher strengths may be obtained than with square weaves of comparable thickness. Higher compressive strengths are realized because the "long shaft" acts as a straight column in comparison to the already buckled column of the crimped fibers in square weaves. Higher tensile stresses may be applied because the long-shaft fibers are not abraded against the fill threads as readily as those of the highly crimped square weaves. These advantages are present to even greater degree with the unidirectional fabrics. Impact strengths are higher, however, in those laminates reinforced with the square-woven fabrics.

Economic reasons may also influence the choice of reinforcement. Thicker cloths have a lower price per pound and require less labor expenditure to achieve a given thickness of the laminate. Waste is considered to be lower using the long-shaft cloths due to ease in removing air pockets which might cause rejection of the part.

Physical Characteristics: In addition to the properties tabulated in TABLE 1, certain characteristics should be considered in any structural design using glass-fabric reinforced laminates.

ELONGATION: Glass-fiber laminates have a low elongation at break of approximately 2 per cent, and yield and ultimate strengths are essentially equivalent. In view of this low elongation, emphasis must be placed on the importance of accurately located rivet and bolt holes in order that the load will be distributed evenly through each member. If not done, exces-

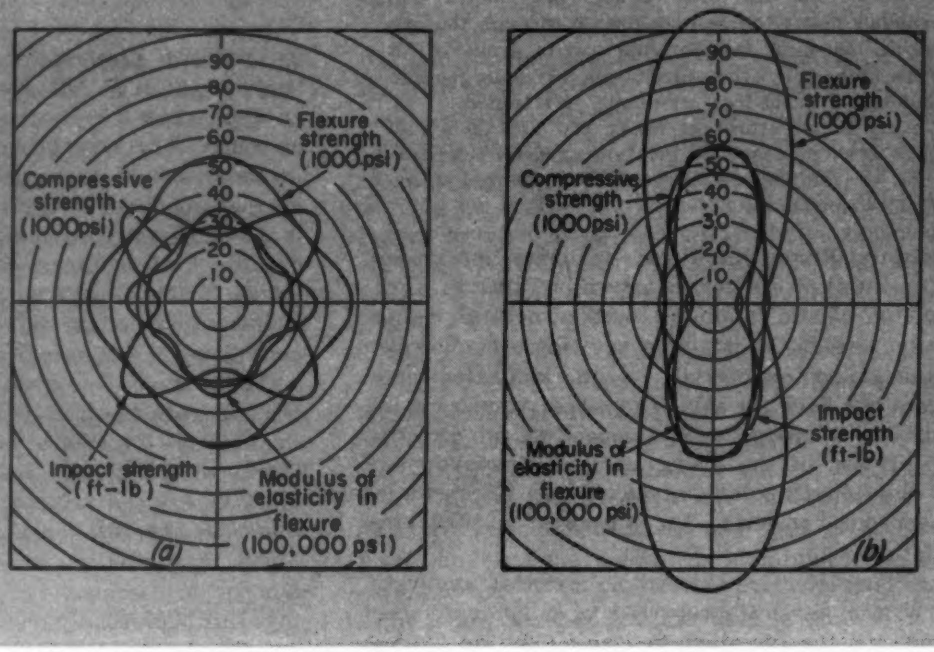


Fig. 7—Difference in physical properties between laminates utilizing a bidirectional cloth, *a*, and a unidirectional cloth, *b*, both parallel-laminated

sive stresses around one or more members will precipitate tearing and consequent failure of the design.

INTERLAMINAR SHEAR STRENGTH: Structural glass-fabric laminates have interlaminar shear strengths of from 1100 to 1800 psi. Secondary (adhesive) bond shear strengths also fall in this range. These values suffer a great decline as loading which tends to cause "peel" is introduced; the design must be such to avoid or minimize peel or delamination.

RAIN-EROSION RESISTANCE: Glass-fabric laminates employed for exterior use in aircraft may be ruined within a few minutes when flying at high speeds through rain, since the laminate is literally eroded with increasing rapidity after the first penetration of the surface is made. Rain erosion may be minimized by:

1. Utilizing structural laminates, which have a minimum of porosity. The lower porosity of these laminates restricts the inroad of erosion up to 25 times as well as highly porous laminates.
2. Making the outer ply or plies of the laminate continuous whenever possible, especially in areas which present an angle of impact of 15 degrees or more in flight through rain. Frontal areas (those flat surfaces having head-on impact) are considered to have angles of impact of 90 degrees.
3. Protecting these areas with a rain-erosion protective coating, *Fig.* 10.

Table 4—Flexural Strength of Typical Polyester Laminates at High Temperature*

Temperature	Ultimate Strength (psi) Laminate A	Laminate B	Laminate C
Room	57,600	50,600	35,900
250 F	31,600	27,800	26,700
300 F	35,300†	26,400	22,600
350 F	24,200	16,500	16,300
400 F	.....	19,400†	12,900
500 F	Fail	Fail	5,200

*Data from unpublished Air Development Force tables. All samples conditioned for 200 hours at test temperature. Laminates listed should not be used at continuous operating temperatures above 350 F. †Discrepancies probably due to aftercuring at test temperature.

MOISTURE RESISTANCE: Glass fabric-polyester laminates decline in strength upon exposure to moisture especially with respect to flexural and compressive strength. Tropical conditions of high humidity and high temperatures cause losses of strength equivalent to or in excess of the values in TABLE 3, which should not be considered as "allowables."

TEMPERATURE EFFECTS: Temperature has considerable effect on the properties of glass fabric-polyester laminates. Increases of from 5000 to 15,000 psi above the strengths as measured at room temperature are noted at temperatures as low as −70 F; conversely the physical properties decline with increasing temperatures as shown in TABLE 4, which again are not "allowable" values.

FATIGUE RESISTANCE: Fatigue tests to date indicate that the S-N curves become essentially horizontal at about 10,000,000 cycles with up to 60-70 per cent drop in strength as compared with the ultimate static strength.

CHEMICAL RESISTANCE: Chemical resistance to various solvents is as follows:

Water	Excellent
Aliphatic hydrocarbons	Excellent
Aromatic hydrocarbons	Excellent
Mineral oils	Excellent
Vegetable oils	Excellent
Chlorinated solvents	Poor
Dilute acids	Excellent
Concentrated acids	Fair
Dilute alkalis	Fair
Concentrated alkalis	Poor

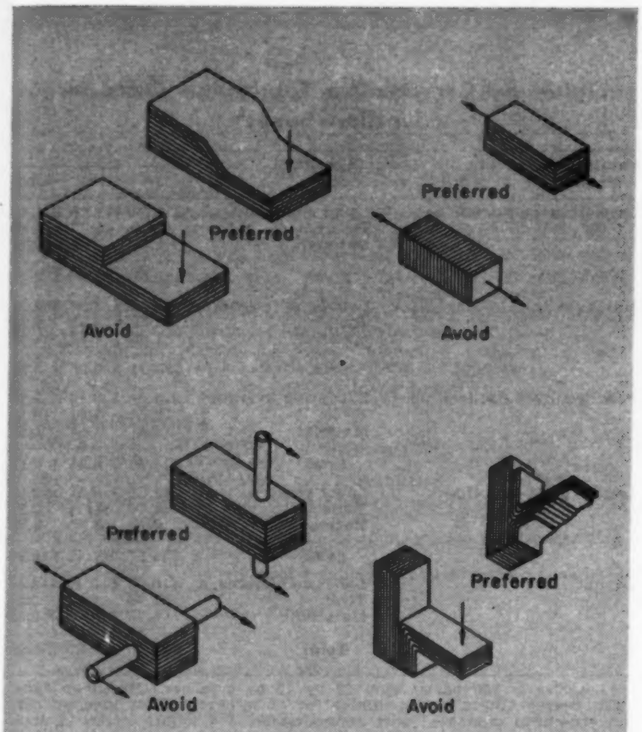


Fig. 8 — Design practices must take into account the nonhomogenous nature of the material

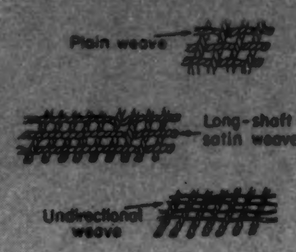


Fig. 9—Types of weave available in glass fabrics

SURFACE ROUGHNESS: Laminates fabricated on plaster mandrels tend to be somewhat rough (250 to 500 microinches) on the surface molded against the plaster while the exterior or bag-side surface has increased roughness and considerable irregularity.

WARPAGE: Glass-fabric laminates may show considerable warpage; the side walls of boxes, for example, tend to bow inward, making the attaching of covers, etc., difficult. The tendency to warp of products having two or more different fabrics may be minimized by employing "balanced" laminates; i.e., the two cloths are symmetric about the central laminate.

Cost and Quantities: Glass-fabric reinforced laminates are relatively expensive. They may "pay their own way," however, if utilized when:

1. Small quantities (1 to 20, for example) are required and form dies, molds, jigs, etc., are not available.
2. Small to moderate quantities of parts with complex configurations are needed, for which dies or welding jigs would be very costly.
3. Mock-up skins and other parts are needed. Economies are increased when lower-cost cotton-fabric fillers are used.
4. Fabrication using more conventional materials would require extensive fastening of many component parts which could be laminated in one piece.
5. Used as optional materials for mat-molded glass-fiber products for small quantities prior to the preparation of tools.
6. Chemical resistance, electrical properties, or light weight are required in conjunction with desirable structural properties.

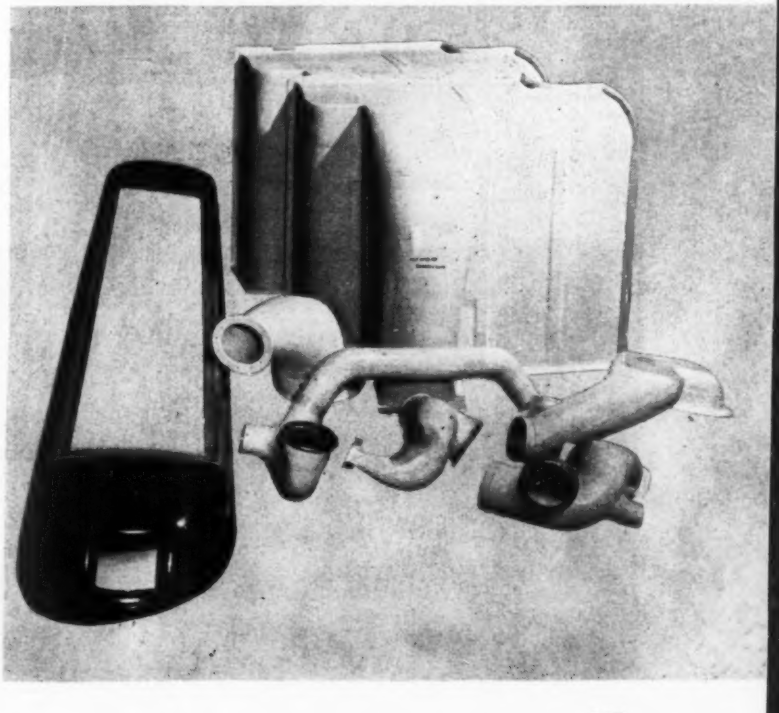
The comparisons listed in TABLE 5, based on figures prepared at Boeing Airplane Co., show comparative costs of various processes based on a lot size of 100 parts. It should be noted that, with the exception of excellent electrical properties combined with desirable structural properties, none of the conditions advantageous to laminated products is present.

If boxlike or hollow, open parts having no undercuts or closed sections are required in quantities in excess of 15 to 30, mat molding should be considered.

Design Considerations: In general, there are no size limitations for laminated parts; however, economical fabrication and usual size of curing ovens imposes a practical limitation of 100 inches in length of single duct-like configurations and about 14 feet in length of structural skins.

Wide ranges of thickness are available, but thickness is generally chosen as a multiple of 0.007 and

Fig. 10—Rain-erosion resistant coating is sometimes employed, as on the fairing at lower left, and metal attaching flanges may be used on ducts



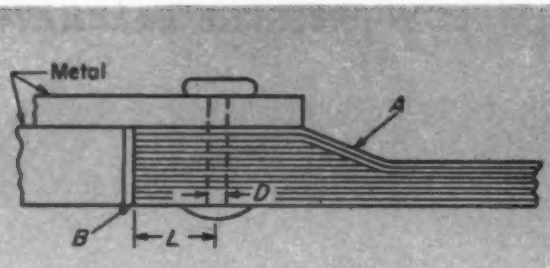


Fig. 11—Typical edge construction for fastener holes

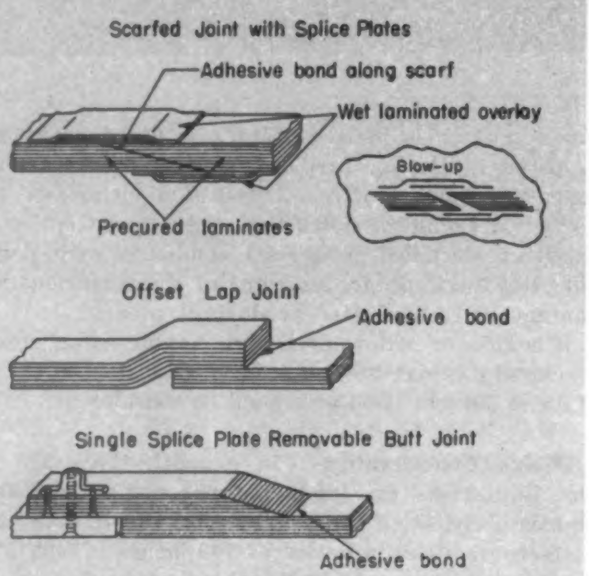


Fig. 12 — Adhesive - bonded joints for laminated parts

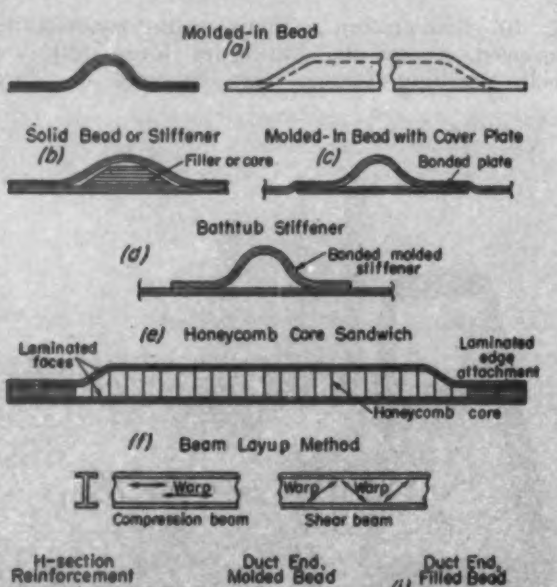


Fig. 13—Stiffener and reinforcement designs, utilizing "molded-in" or bonded stiffeners

Table 5—Comparative Fabrication Costs for Junction Boxes*

Fabrication Method	Cost Item	Cost 10	Cost 100	Cost 1000
Deep Drawing (aluminum, 0.051-inch thick)	Labor and Overhead	$ 4.09	$ 1.39	$ 1.39
	Tools†	47.50	4.75	0.48
	Material	1.02	1.02	1.02
	Total	$52.61	$ 7.16	$ 2.89
Mat Molding (0.078-inch thick)	Labor and Overhead	$ 3.09	$ 2.08	$ 2.08
	Tools	25.20	2.52	0.25
	Material	1.65	1.65	1.65
	Total	$29.94	$ 6.25	$ 3.98
Postforming (0.063-inch thick)	Labor and Overhead	$ 5.27	$ 3.16	$ 2.76
	Tools	18.14	1.81	0.18
	Material	1.57	1.57	1.57
	Total	$24.98	$ 6.54	$ 4.51
Layup (0.051-inch thick)	Labor and Overhead	$12.32	$ 9.52	$ 9.52
	Tools	11.40	1.14	0.11
	Material	6.75	6.75	6.75
	Total	$30.47	$17.41	$16.38
Layup§	Labor and Overhead	$16.05	$12.40	$12.40
	Tools	17.20	1.72	0.17
	Material	6.75	6.75	6.75
	Total	$40.00	$20.87	$19.32

*Lot size is 100 parts, each 12 by 12 by 4 inches. Based on June, 1951, costs. †Form dies available for most parts. §Not junction box, but structural laminated part approximately 144 square inches in area.

0.014-inch, the nominal thickness per laminated ply of many glass-fiber fabrics. Laminates should usually be thicker than 0.020-inch, with approximately 25 per cent additional thickness at flanges and other attaching areas, especially with ducts, etc.

DRAFT: At least one degree of draft should be provided on all laminates of boxlike or other hollow, open configuration. This draft allowance provides ease of fabrication of the plaster mandrels, permits use of permanent mandrels if desirable, and facilitates changing to other methods of manufacturing such as mat molding if larger quantities are required.

CORNER AND FILLET RADII: Inside corner and fillet radii of 1/8 to 1/4-inch or larger should be incorporated. Sharp corners and fillets, particularly the latter, result in resin-rich areas which are brittle and often rough and irregular.

TOLERANCES: Thickness tolerances are difficult to meet in corners and other areas where tailoring and lapping of the fabric is required. Overall thickness of the part, however, can almost always be held to within 0.02-inch of the nominal dimension. Length and width tolerances should be as large as possible to effect maximum economies.

HOLES AND OPENINGS: Cutouts may be made by drilling, routing, sawing and punching the cured laminate. Some delamination of the cut edge will result with damage penetrating from 1/32 to 1/8-inch. Structural laminates may be abrasive-sawed with negligible edge damage. Drilled holes tend to "close up" and should be reamed if accuracy is required. On drilled holes, tolerances of $\pm$0.003-inch should be allowed.

METHODS OF FASTENING: Laminated parts may be riveted, bolted, or bonded to each other, to wood or to phenolic.

Rivets and Bolts: If rivets are used, a soft mate-

Table 6—Related Federal and Military Specifications

Number	Title
Military Specifications*	
MIL-C-7439	Coating, rain erosion resistant for plastic laminates.
MIL-G-1140	Glass fiber; yarn, cordage sleeving, cloth and tape.
MIL-P-406-A	Plastics, organic; general specifications, test methods.
MIL-P-7094-A	Plastic parts, aircraft exterior, general requirements and test for rain erosion protection of.
MIL-P-8013	Plastic materials, glass fabric base, low pressure laminated, aircraft structural.
MIL-P-8073	Plastic honeycomb; laminated glass fabric base, core material, for aircraft application.
MIL-R-7575	Resin, low-pressure laminating.
Air Force Specifications	
USAF 12043 12043-A	Plastic parts, molded, general specification for inspection of.
USAF 12049	Resin, low-pressure laminating.
USAF 12050	Core material; laminated glass fabric base plastic honeycomb.
USAF 12051	Plastic materials, laminated glass fabric base, low-pressure molded.
USAF 12053	Plastic; molded sandwich construction, honeycomb core.
USAF 40856	Radomes, aircraft.
Document	
Air Materiel Command	Radome Test Procedure.

* All U. S. Air Force sponsored.

rial such as aluminum is employed since harder rivets will damage the laminated member. Nonstructural laminates or conditions of light loading should be riveted with 2S-F rivets. Where structural loads are present, 2S-F, A17S-T3 or 56S rivets should be employed in sizes up to 3/16-inch; rivets harder than 56S should not be employed. Steel washers should be used under the driven head where the head is adjacent to a laminated member. In addition to minimizing driving damage, natural expansion of the rivet shank, resulting in internal crushing of the laminate, is minimized.

Above 3/16-inch, bolts should be considered. Typical blind fasteners are satisfactory. Lockbolts can also be used, but should be of 75S-T6 aluminum, in which case no washers are required.

Minimum edge distances for fastener holes should be $L = 2D + 0.08$ where D = hole diameter, inches; and L = length from hole centerline to edge of part, inches (see ***Fig.*** 11).

A thickness increase is desirable at attachment points, since glass fabric-reinforced laminates have essentially no ductility, with consequent lack of relief at areas of stress concentration. Net area efficiencies range from 50 to 75 per cent, as compared with 90 to 100 per cent for metals. Continuity of outer plies (point *A* in ***Fig.*** 11) is also desirable.

For outdoor applications, butt ends of the laminated member (*B* in ***Fig.*** 11) should be sealed with a coat of air-drying resin to minimize encroachment of the laminate by moisture with resulting decline in strength. This procedure is less important if new water-repellent finishes are employed on the glass fabric.

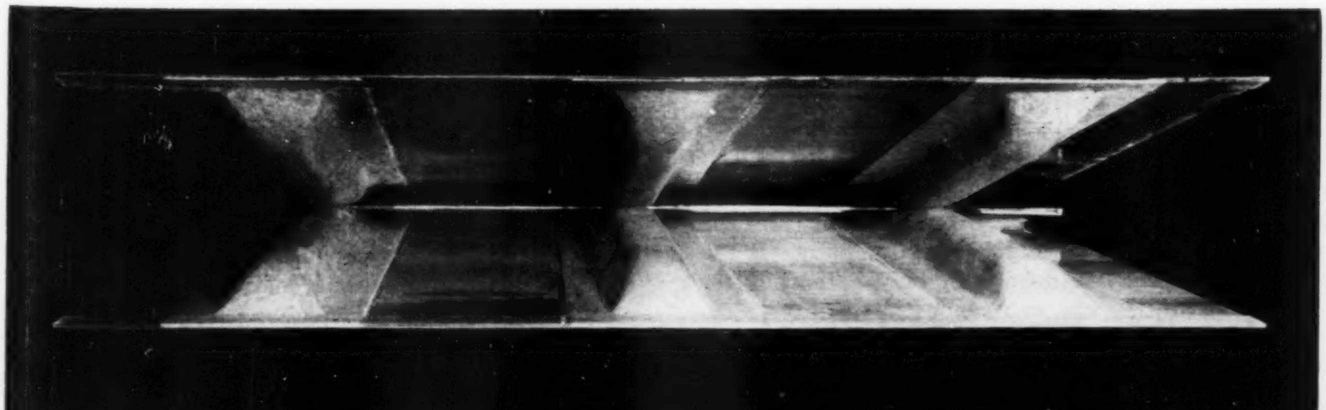
ADHESIVE BONDING: Using simple lap-type specimens of 1 inch width and 0.5-inch lap in laminated material of 0.05 to 0.06-inch thickness, ultimate stresses of 1000 to 1400 psi may be attained at short-time loading rates using polyester resins as adhesives. Using newly developed epoxy resins, ultimate stresses of 2000 to 3000 psi may be attained under similar circumstances. Typical joints are shown in ***Fig.*** 12. Loading that introduces "peel" cannot efficiently be handled with adhesive-bonded joints.

Adhesive bonding is frequently facilitated and improved by adding, in the original layup, a "peel ply"—an extra ply of glass fabric in the intended faying surface areas. This is peeled immediately prior to bonding, presenting a uniformly roughened surface, free of contamination. Use of a peel ply also eliminates the extra labor of sanding.

STIFFENERS: Integral reinforcements, such as flanges, beads and ribs, may be incorporated in the component during layup merely by modification of the plaster mandrel, ***Fig.*** 13*a*.

Beads should be used to break up large, flat areas. If a molded-in bead is used as in ***Fig.*** 13*a*, it must be formed on the mandrel. Filler material for a solid

Fig. 14—Test section of a trailing-edge antenna, with structural-grade, low-pressure laminate skins and molded laminated bathtub stiffeners



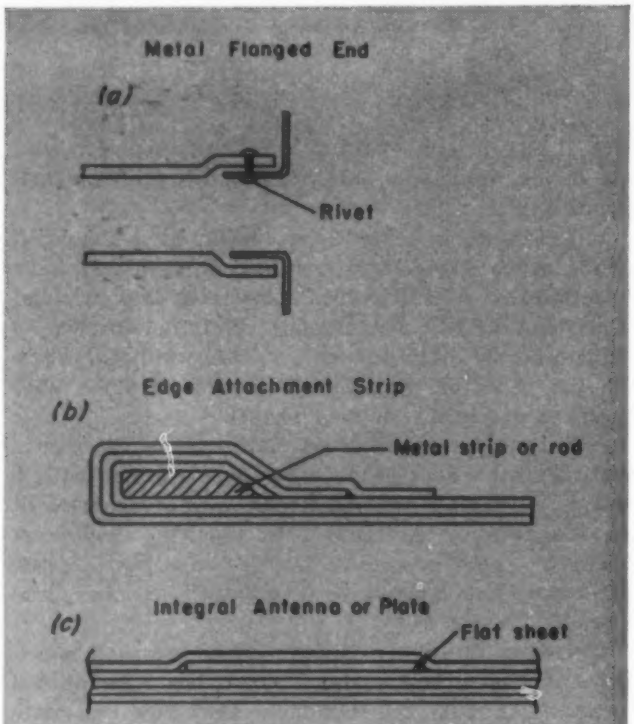


Fig. 15 — Metal reinforcements and inserts, which provide an alternate method of stiffening edges

bead, *Fig.* 13*b*, may be additional plies, a cut piece of cured laminate or wood. However, unless a low-density core is used, such as cellular cellulose acetate, or balsa wood, weight increase may be excessive. One of the advantages of this reinforcement is that no change in the mandrel mold is needed to change designs, since the filler is added at layup.

A "molded-in" bead with cover plate, *Fig.* 13*c*, is often used where a smooth interior surface is needed, for instance, to diminish pressure drop in ducts. The bathtub stiffener or hat stiffener, usually with closed ends, *Fig.* 13*d* accomplishes the same purpose, and can also be used on commercially produced thin, flat panels for reinforcement, *Fig.* 14.

If a strong, lightweight panel is needed, the honeycomb-core sandwich structure of *Fig.* 13*e* might be considered. In this type of construction, typical of radomes, the honeycomb core is usually bonded to laminate-construction edges which serve as attachment members to other parts of the assembly. Sandwich structures are, however, usually more expensive than monolithic or bonded structures.

In H or I-beam sections, a certain degree of flexibility is available to the designer in specifying the direction of lamination. Thus, if the beam is used as a compression member, *Fig.* 13*f*, the warp fibers in the web and flanges can be aligned longitudinally. If the beam acts as a shear member, however, the plies of fabric constituting the web can be aligned at 45 degrees to the longitudinal axis to achieve maximum shear stress. In order to fill the natural void at the junction of the two interior radii, *Fig.* 13*g*, a triangular-section filler strip is usually used.

Stiffeners applicable to duct ends where attachment to flexible ducts is made include modifications of those outlined earlier, namely, a molded-in bead or a filled bead, *Fig.* 13*h* and *i*. The filler in the latter type may be cord, soft wire, etc., laminated in place.

Metal reinforcements and inserts are not very widely used as yet because, in many cases, of poor adhesion of the laminate to the metal. Scrupulous cleanliness must be observed and the metal surfaces suitably roughened; very little work has been done with primers in this respect. Copper, if employed, should be silver plated to avoid possible inhibition of the polyester resin.

A metal flanged end may be employed, *Fig.* 15*a*, with or without a rivet. Ducts may also use this type of design or may have beaded ends as in *Fig.* 13*i*. Other metal inserts may be a metal strip or rod, *Fig.* 15*b*, if an edge attachment strip is needed, or flat sheets laminated in place, *Fig.* 15*c*, as used for integral antennas.

Applicable Military Specifications: A number of applicable military specifications and documents are listed in TABLE 6. Of these, USAF Specifications 12053 and Military Specification MIL-P-8013 are of primary interest to designers.

ACKNOWLEDGMENT

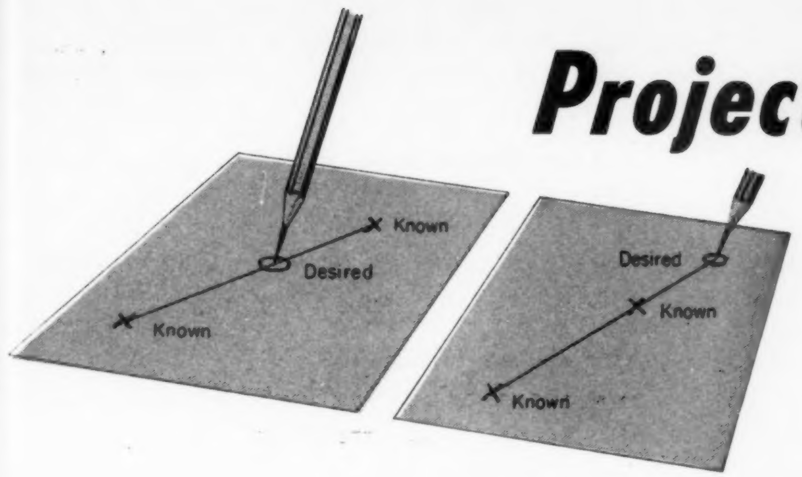
The author wishes to acknowledge, with appreciation, the co-operation of Pacific Plastics Co. in supplying several photographs used in this article.

They Say...

"The most important [method of increasing industrial productivity], in my opinion, is that of effecting complete co-ordination of product development with development of production facilities and tools to manufacture the product."—F. R. BENEDICT, *assistant engineering manager, industrial products divisions, Westinghouse Electric Corp.*

"There is a definite place for women engineers in industry. . . With far too few engineers being trained today in our technical schools and colleges, engineers, even more than any other group of people, have a responsibility to encourage and even recruit young people to take up engineering careers. In carrying out this responsibility, engineers should not overlook the potential engineering talent possessed by many young women."—WILLIAM V. KAHLER, *president, Illinois Bell Telephone Co.*

". . . if atomic energy is ever to be made importantly useful in peacetime applications, we must depend to a large measure in the coming years on a tri-partite team. Industry, educational institutions, and government must each take an effective part in this development. This team must be strong as individuals and particularly strong as a team if we are to be successful."—T. KEITH GLENNAN, *former commissioner, United States Atomic Energy Commission.*



Projecting Data

. . . by algebraic and graphical techniques yields valid results and cuts engineering costs

By Edward C. Varnum

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OBTAINING the most benefit from available data is a direct route to reduced engineering costs and improved design. Often the means toward such ends are extremely simple, and the results more valid than for other more complex analytical procedures. How existing data can be projected by both algebraic and graphical methods to obtain desired new data is summarized in this article.

In calculations involving motions of mechanisms or data derived from physical tests, attention usually can be concentrated on only two variables, even though more than two may be involved in the total problem. One of these variables can be thought of as varying independently, while the second is dependent on the first. Basic calculations or test results thus provide parallel lists of values of these variables. The question then arises: what would have happened if the independent variable had been different from any of the variables in the list?

If the value in question is exceeded by some of the listed values and if it exceeds some of the other known values, then "inside projection" or interpolation of the data is required. On the other hand, if the value exceeds all the known values or if it is exceeded by all of the known values, "outside projection" or extrapolation of the data is called for.

Linear Interpolation: Of the two methods of projecting data, the one which seems the safer is interpolation. The simplest type of inside projection, of course, is linear interpolation, so called because a straight line is assumed to join two known data points and the desired data are assumed to lie on this same line.

Linear interpolation is a common everyday operation, of course, being used with tables of logs, trigonometric functions, etc. A simple example is

Independent Variable	Dependent Variable
713	528
700	x
629	372

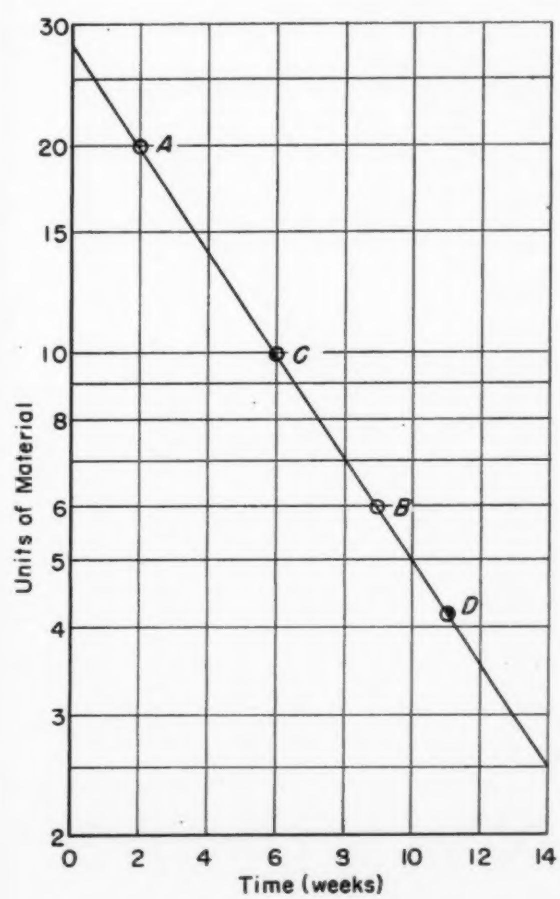


Fig. 1 — Semilogarithmic paper gives a straight line for data conforming to exponential equations of the form in Equations 6 and 7

The customary solution is

$$\frac{700 - 629}{713 - 629} = \frac{x - 372}{528 - 372}$$

$$x = \frac{156(71)}{84} + 372 = 503.9$$

The simplicity of this direct method makes it useful in instances which occur infrequently. For mass production of such linear interpolations, however, there is a method which is more convenient for use with calculating machines:

$$x = \frac{(713 - 700)(372) + (700 - 629)(528)}{(713 - 700) + (700 - 629)}$$

$$= \frac{13(372) + 71(528)}{13 + 71} = 503.9$$

The multiplications, additions and division are performed easily by machine calculation. If the 13 and 71 are used as multipliers and they are not cleared between the two multiplications, their sum will appear in the multiplier window of the calculator. Also, there is a "cross-ruffing" with the 13 being multiplied by the 372 and the 71 by the 528. Although it is necessary to perform two subtractions, it often happens that these subtractions are easy to do mentally, because the independent variable is frequently a simple number.

Linear Extrapolation: For use in isolated examples, the conventional direct method for extrapolation is quite simple. Data might be

Independent Variable	Dependent Variable
376	216
389	239
400	x

The ordinary solution is

$$\frac{400 - 376}{389 - 376} = \frac{x - 216}{239 - 216}$$

$$x = \frac{24(23)}{13} + 216 = 258.5$$

As with interpolation, there is a machine method of extrapolation which is much better when a desk calculator is available:

$$x = \frac{(400 - 376)(239) - (400 - 389)(216)}{(400 - 376) - (400 - 389)}$$

$$= \frac{24(239) - 11(216)}{24 - 11} = 258.5$$

Quadratic Interpolation: Linear methods are generally adequate only when the increments are small or the relationship is known to be linear or nearly so. When the increments are greater or the curvature is suspected to be significant, other methods which accommodate "curvature" of the data are best employed. Perhaps the most simple technique is known as quadratic interpolation.

The most general approach to quadratic interpolation is to assume a quadratic function relating the two

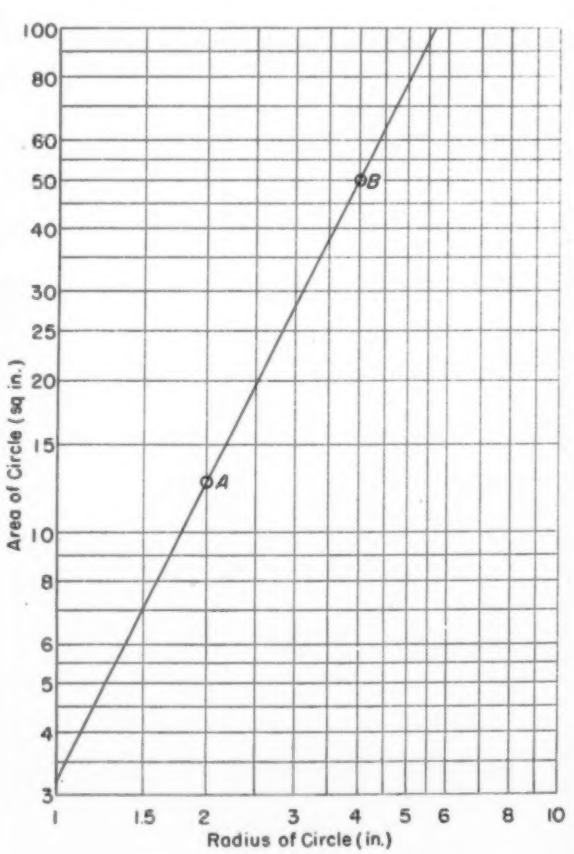


Fig. 2—When both axes are logarithmic, exponential curves of the type defined by Equations 8 and 9 are straight lines

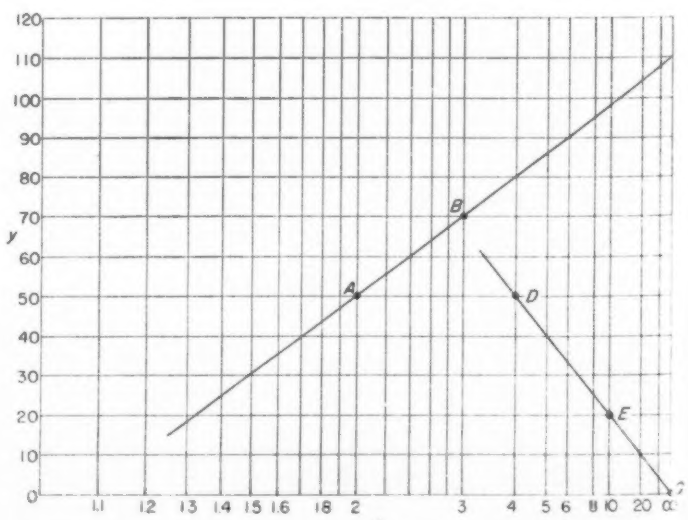


Fig. 3—When the x-axis is ruled reciprocally, data such as speed times torque for horsepower plots as a straight line

variables in question. The quadratic function will have three undetermined constants which can be found by placing three pairs of variable values into the function and solving the resulting three linear equations for the three constants:

$$y = ax^2 + bx + c \qquad (1)$$

Substituting three pairs of known values of x and y into Equation 1 gives the following equations:

$$y_1 = ax_1^2 + bx_1 + c$$

$$y_2 = ax_2^2 + bx_2 + c$$

$$y_3 = ax_3^2 + bx_3 + c$$

Then a, b and c are determined by simultaneous solution of these equations. The value of y for any desired value of x can be found by use of Equation 1. This method can be used for other functions besides the quadratic function. That is, there can be employed a function with n constants. Then, n pairs of known values can be used to obtain n equations in n unknowns, and the constants in the function can be evaluated.

If this general method of interpolation is extended, it becomes numerically involved unless there are some further restrictions on the variables. One such simplifying restriction is that the independent variables be evenly spaced; that is, x_2 is the average of x_1 and x_3, etc. With this condition the calculations reduce to the following simplified result:

$$y = (0.5\,p^2 - 1.5\,p + 1)\,y_1 + (2\,p - p^2)\,y_2 - (0.5\,p - 0.5\,p^2)\,y_3 \qquad (2)$$

where p is the fraction of the difference from x_2 to x_1 which is taken up by the difference between x and x_1, or, more precisely,

$$p = \frac{x - x_1}{x_2 - x_1} \qquad (3)$$

For the value $p = 1/2$ (that is, x being the average of x_1 and x_2) Equation 2 becomes

$$y = 0.375\,y_1 + 0.75\,y_2 - 0.125\,y_3 \qquad (4)$$

Values of the three parentheses in Equation 2 have been calculated for various values of p and are known as three-point La Grange interpolation coefficients[1] because three pairs of values of the variables are required for the interpolation. Tables of values for four-point and five-point interpolation have also been calculated. These tables are based on assumed cubic and fourth-degree functions, respectively, as well as on the equal spacing of the known values of the independent variables.

For five-point interpolation the necessary formulas are:

$$y = A_{-2}\,y_{-2} + A_{-1}\,y_{-1} + A_0\,y_0 + A_1\,y_1 + A_2\,y_2 \qquad (5)$$

where y_{-2}, y_{-1}, y_0, y_1 and y_2 are successive values of the dependent variable corresponding to equispaced values of the independent variable and the coefficients are given by

$$A_{-2} = \frac{p(1 - p^2)(2 - p)}{24}$$

$$A_{-1} = \frac{-\,p(1 - p)(4 - p^2)}{6}$$

$$A_0 = \frac{(1 - p^2)(4 - p^2)}{4}$$

$$A_1 = \frac{p(1 + p)(4 - p^2)}{6}$$

$$A_2 = \frac{-\,p(1 - p^2)(p + 2)}{24}$$

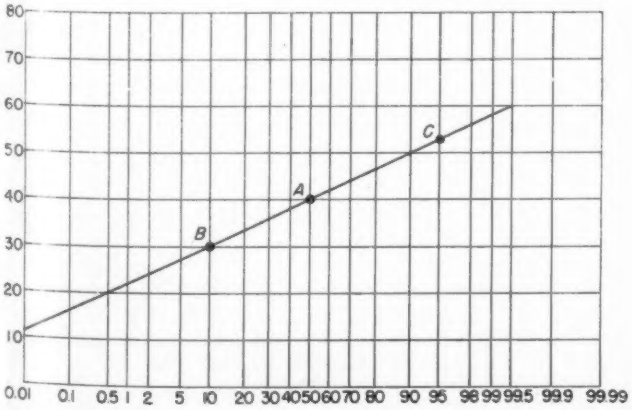
where

$$p = \frac{x - x_0}{x_1 - x_0}$$

Graphical Interpolation and Extrapolation: The preceding numerical methods of projection of data become lengthy and unnecessarily tedious if the accuracy required does not warrant their use. For less accurate results, graphical methods may be employed in an obvious manner. That is, one can plot the known data as points on graph paper, draw a curve through these points and read off the desired dependent variables corresponding to the given dependent variable.

But the nature of the graph paper can be a quite important factor. If the data appear to be linear or if accuracy is of little concern, conventional paper with equispaced co-ordinate increments for both axes is satisfactory. But often, when the data would plot as a curve on rectangular co-ordinate paper, accuracy between known points may be sacrificed. Also, an equation that fits the data often may be desired. Curves are most easily identified and fitted with equations if they can be validly reproduced as straight lines by distortion of the co-ordinate requirements. Special nonrectangular graph paper may be the means to an effective solution.

Fig. 4—Probability paper, having the x-axis ruled according to the accumulated frequency of the normal probability curve, is useful for normality determinations



[1] References are tabulated at end of article.

Semilogarithmic Paper: With one axis (y) ruled logarithmically the basic equation for a straight line becomes

$$\log y = mx + b \qquad (6)$$

or,

$$y = ce^{mx} \qquad (7)$$

An example of application of Equation 7 is in radioactive decay in which m is negative, x = time, y = amount of radioactive material corresponding to time x, and c = amount of material at time $x = 0$. If the amount of material is known for two different times, the amount at any desired time can be found by drawing a straight line between the plotted points for the known data and reading off the value of y corresponding to the desired time x. As illustrated in *Fig.* 1, assume that 20 units of a radioactive substance are on hand 2 weeks after purchase, while it is found that only 6 units remain after 9 weeks. Plotting points A and B and joining them by a line show that 10 units existed after 6 weeks as indicated by point C. Extrapolation is also possible; at point D, 4.2 units will be on hand after 11 weeks.

For any two variables related as shown in Equations 6 and 7, semilogarithmic graph paper is ideal for graphical interpolation or extrapolation. The process illustrated can often be advantageously reversed. That is, data are plotted on semilogarithmic paper, a straight line is established and the underlying equation relating the variables is then written.

Logarithmic Paper: With both axes ruled logarithmically, the basic equation of a straight line becomes

$$\log y = m \log x + b \qquad (8)$$

which can be written in exponential form as

$$y = cx^m \qquad (9)$$

A well-known illustration of Equation 9 is given in *Fig.* 2 where y = area of a circle, x = radius of the circle, $m = 2$, and $c = \pi = 3.1416$. The line may be plotted from any two points such as point A for $x = 2$, $y = 12.5664$ and point B for $x = 4$, $y = 50.2656$. Inside or outside projection of the data may be used to find the area corresponding to other radii. The value of m may be set at 3 to plot the volume of a sphere as a function of its radius, which will also be a straight line but with a steeper slope.

For any of the large group of functions expressible in Equation 8 or 9, logarithmic paper is convenient for graphical interpolation or extrapolation. As with the previous type of graph paper, the underlying equation may not be known but a plot of the data at hand may produce a reasonably straight line from which an underlying equation can be written. The obvious method of obtaining the equation of an empirical line is to choose two clear points and substitute their numerical values into Equation 8. Solving the resulting linear equations for m and b yields the constants in the formula.

Reciprocal Paper: With the x-axis ruled reciprocally, the basic general equation can be written

$$y = \frac{m}{x} + b \qquad (10)$$

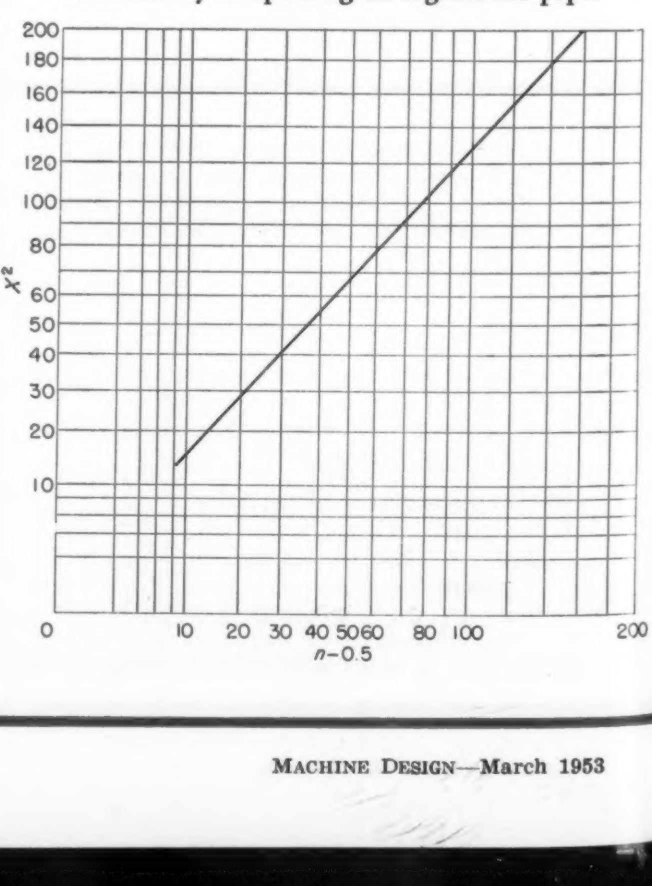
For $b = 0$, the general equation becomes

$$xy = m \qquad (11)$$

which is recognized as applicable to the pressure-volume equation or to the speed-torque expression for horsepower, to mention only two instances in which two variables are multiplied together. If two variables are related by Equation 10, interpolation or extrapolation may be performed as illustrated by line AB in *Fig.* 3 which is plotted from the known values of $x = 2$, $y = 50$ for point A and $x = 3$, $y = 70$ for point B. The value of y corresponding to any desired value of x can be read directly from the line. Substituting the values for points A and B into Equation 10 yields $m = 120$, $b = 110$. The value of b can always be read directly from the left-hand y-scale. All graphs of Equation 11, where m is constant for each line, will pass through point C with $x = \infty$, $y = 0$. The value of m for any such line passing through C can be found simply by multiplying the x and y values for any point of the line. For line DE shown in *Fig.* 3, the value of m is 200.

Frequently, the basic underlying equation relating variables of a problem is not known and there are more than two plot points given. In a search for a reasonable relationship between variables, they can be plotted on reciprocal paper to test the validity of the underlying law expressed by Equation 10. If a straight line results from several points, this line may then be used for graphical interpolation or extrapola-

Fig. 5—Square-root graph paper plots straight lines for some data that do not transform readily for plotting on logarithmic paper



tion under the assumption that the law continues to hold over the range in question.

Probability Paper: Another illustration on non-linear rulings is found in the field of statistics where the notion of the normal probability curve plays an important role. The x-axis in *Fig.* 4 is ruled according to the accumulated frequency of the normal probability curve in which 50 per cent of the values are 40 or less (point A) while 10 per cent of the values are 30 or below (point B). Line AB may be extrapolated to point C, indicating that 95 per cent of the distribution will be 52.8 or less. A plot of accumulated frequency distributions on probability paper shows the proximity of the data to a normal distribution. When this type of paper is used for normality tests, the extreme high and low percentage values must not be considered as seriously as the midvalues.

Square-Root Graph Paper: Occasionally one encounters situations in which the variables involved can be approximated by the equation

$$\sqrt{y} = m\sqrt{x} + b \qquad (12)$$

If the constant b were not present, the values of x and y would plot as a straight line on logarithmic paper because the equation would become, after taking logarithms and multiplying by 2

$$\log y = 2 \log m + \log x \qquad (13)$$

However, the presence of the b term in Equation 12 hinders its transformation into a convenient logarithmic form and necessitates a special graph paper. The required paper is prepared by drawing lines at distances proportional to the square roots of the integers, as shown in *Fig.* 5.

A specific numerical example arises in connection with the Chi-square tests[2] in which the distribution of $\sqrt{2X^2}$ is approximately a normal distribution with a mean of $\sqrt{2n-1}$ and a unit standard deviation. At the 5 per cent level of significance, the deviation of $\sqrt{2X^2}$ from $\sqrt{2n-1}$ is 1.645 standard deviations, so that

$$\sqrt{2X^2} = \sqrt{2n-1} + 1.645 \qquad (14)$$

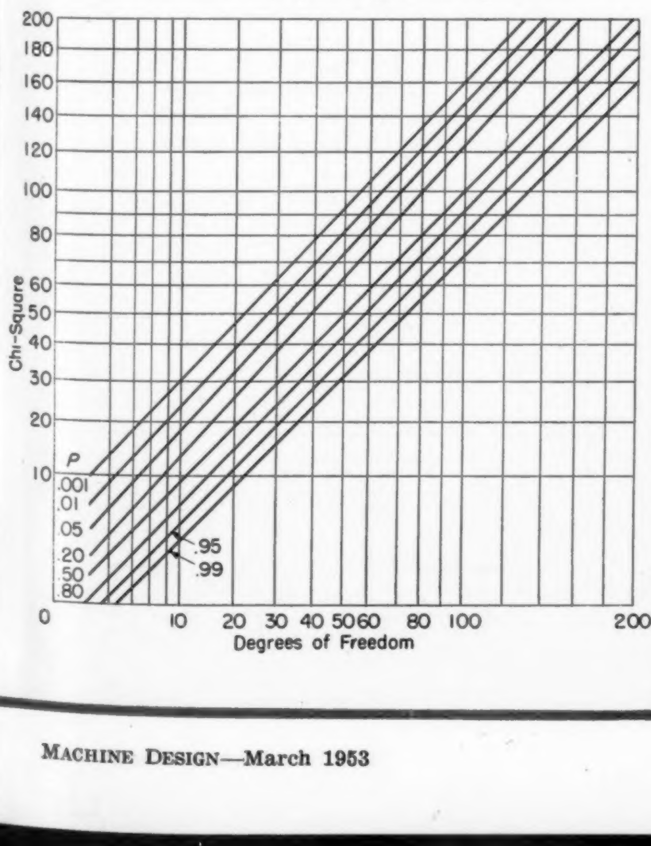
Dividing both sides of this equation by the square root of 2 gives

$$\sqrt{X^2} = \sqrt{n-0.5} + 1.163 \qquad (15)$$

Equation 15 is an example of the general Equation 12 with $y = X^2$, $m = 1$, $x = n - 0.5$, $b = 1.163$ so that the relationship between X^2 at the per cent level and a number which is 0.5 less than the degrees of freedom in the test will plot as a straight line on square-root paper, providing the degrees of freedom exceed a sufficient value, usually taken as 30. The line corresponding to Equation 15 is plotted in *Fig.* 5.

Inasmuch as the normality of the Chi-square distribution is only an approximation, especially for the small values of n, the approximation was carried still further by neglecting the 0.5 in the relation between n and x, and the values of X^2 at the 0.001, 0.01, 0.05, 0.20, 0.50, 0.80, 0.95 and 0.99 levels were plotted on square-root paper as shown in *Fig.* 6 with degrees of freedom as x and Chi-square as y. The result was a set of eight lines which were both straight and parallel for practical purposes.

Fig. 6—Chi-square distribution plotted on square-root paper, resulting in a family of lines that are nearly straight and parallel



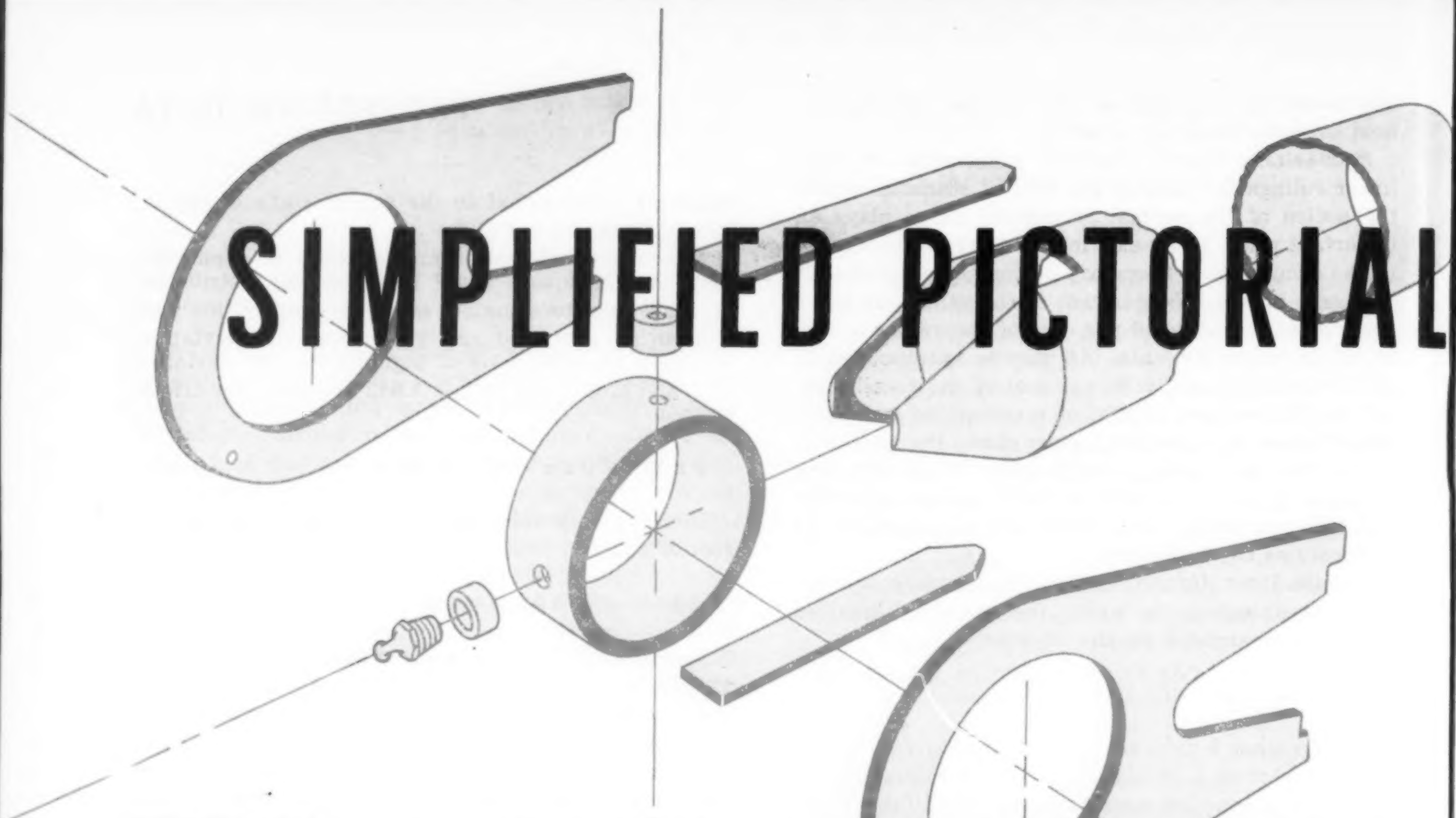
Tailored Scales: Although all types of graph paper mentioned may not be obtainable in every engineering department file, they are available in quantity from most suppliers. These examples do not exhaust the types of printed graph papers prepared for in-plant use.

After this demonstration that various physical problems and statistical functions can be graphed as straight lines by an analysis of the underlying aquations, one might wonder whether similar results can be obtained without knowing the basic equations or without trying all the available kinds of graph paper. This question is answered in a very clear manner in a recent article[3] which describes how to construct distorted scales. After all, the five kinds of graph paper described in this article are merely combinations of distorted scales whose purpose is to make the data plot as a straight line so that graphical linear interpolation can be used.

References

1. *Tables of Lagrangian Interpolation Coefficients,* Columbia University Press, New York, 1944. (For 3 and 4 points, p advances by steps of 0.0001; for 5, 6, 7, and 8 points, p advances by 0.001 steps; for 9, 10, and 11 points p advances by 0.01 steps.)
2. W. A. Ring and E. C. Varnum—"Chi-Square Test," Machine Design, Vol. 23, No. 11, Nov. 1951, Pages 115-117.
3. John Baude—"Simplified Nomograph Construction," Machine Design, Vol. 24, No. 5, May 1952, Pages 155-158.

SIMPLIFIED PICTORIAL



PERSPECTIVE is easy! Engineers and draftsmen can, with no previous experience, produce creditable oblique (three-point) perspective drawings from unscalable sketches with only a few hours study and practice. Wading through the myriad exercises usually thought essential to attain the level of angular (two-point) measuring-point perspective is not necessary. And two-point perspective, usually employed in the architectural field, can be replaced by three-point perspective which is more adequate for engineering, since objects to be drawn are often complex and contain many curves.

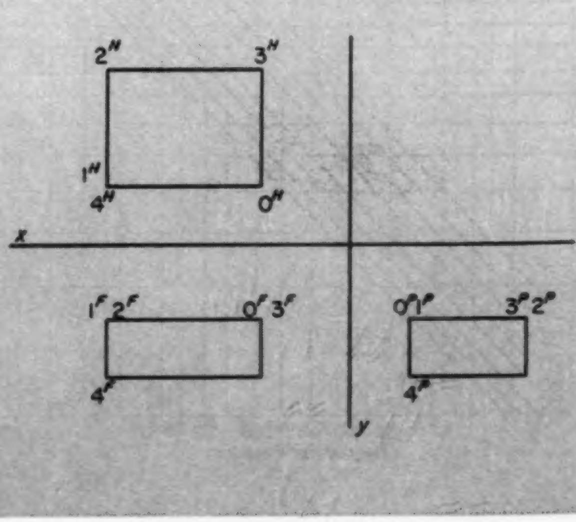
Constructions outlined in this article may not have to be used frequently, but must be understood thoroughly to make intelligent use of the many aids and devices now available to the engineering draftsman or engineering artist. These constructions are simple, fundamental operations. Many textbooks contain innumerable "tricks of the trade," which the expert must employ to attain a high degree of efficiency but which are not really necessary to understand basic concepts of pictorial drawing.

Pictorial projection in general is presented in many different ways, and textbooks list a large number of minutely different forms. A forthcoming American Standard on Drafting Room Practice lists only three—oblique, axonometric, and perspective. In this article, the classification has been reduced still further. The first general group—oblique—is relatively simple and is adequately presented in many textbooks. The remaining classification includes all axonometric (isometric, dimetric, trimetric) projections and all perspective projections.

Axonometric Projections: In axonometric or perspective projections, the object to be presented is usually arranged with its principal features (axes, faces, etc.) parallel and perpendicular to a set of three mutually perpendicular reference planes, as is done to produce a conventional multiview drawing. A fourth plane, the picture plane, is then added. In general this picture plane is inclined to all three of the perpendicular reference planes (or axes). The orthographic projection of the object on this inclined picture plane is a true axonometric projection. A "central projection" of the object on this plane is a perspective. The definition of central projection as used in this article is simple: The projection of an object on a plane by means of projectors (rays) which intersect at a real point.

Thus the only difference between any axonometric

Fig. 1 — Conventional three-view drawing of a block with arbitrarily chosen *x* and *y* axes



L DRAWING

By S. B. Elrod
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Pictorial drawing is rapidly gaining ground as one of the simplest, easiest to understand methods of presenting engineering and manufacturing information. In this article, a complete picture of the fundamental methods used in axonometric and perspective drawings is presented—and the basic simplicity of construction and theory is clearly demonstrated.

projection and any perspective projection is simply whesther or not the rays intersect at a real point or at an ideal point infinitely removed from the picture plane. The process employed in producing such drawings can also be quite similar, as will be shown later.

Only the fundamentals of exact axonometric projection will be presented as applied to a simple rectangular block. Comprehensive coverage and many refinements of the method are available, however, for those interested in the details.[1]

A conventional multiview drawing of the block is shown in *Fig.* 1, with the x and y axes arbitrarily chosen. The pictorial (axonometric) view of these projections on their respective planes, prior to their revolution into coincidence with the frontal plane, is shown in *Fig.* 2. The block itself is shown in position in *Fig.* 3. None of the lines of the block are directly scalable in either of these figures, whereas in *Fig.* 1 all lines were either scalable or shown as points.

Triangle *A-B-C* is drawn with sides perpendicular to the respective axes. Since the x, y, and z axes shown here represent three mutually perpendicular lines, triangle *A-B-C* is normal to the line of sight,

[1] References are tabulated at end of article.

Fig. 2—Axonometric view of the three projections on their respective planes

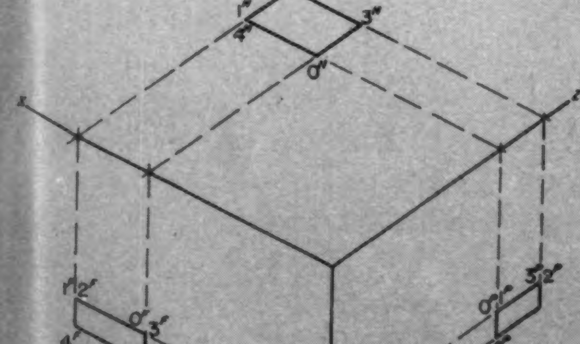
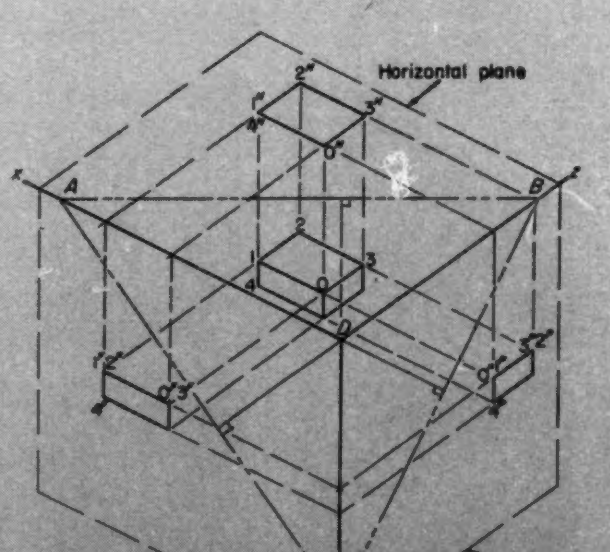


Fig. 3—Right—Block in position with traces of picture plane on the horizontal, frontal and profile plane



since the three sides are each perpendicular to one of the axes. To those who are familiar with the trace representation of planes, the sides of this triangle represent simply the *H, F,* and *P* traces of the picture plane. Some prefer to visualize it as merely a corner cut from a rectangular block.

Since the three sides of triangle *A-B-C* are normal to the line of sight, any line or plane perpendicular to one of them will appear as a line perpendicular to that side. Thus a line from point 3 in space to 3^P perpendicular to the profile (y-z) plane and parallel to the x-axis is perpendicular to side *B-C*. The plane containing 3-3^P and perpendicular to *B-C* will appear as the same line in *Fig.* 3. Likewise, the plane containing 3-3^H and perpendicular to *A-B* appears as the straight line 3-3^H, and the plane containing 3-3^F and perpendicular to *A-C* appears similarly.

These three planes, being perpendicular to *A-B-C* and containing point 3 in space, will intersect in a line through point 3 which is perpendicular to the picture plane. The intersection of this line and picture plane *A-B-C* is the orthographic projection of point 3. Since *Fig.* 3 is a view normal to the picture plane, point 3 in space and its orthographic projection appear at the same point. The same logic holds for other points.

The fact has been established that points on the object and their principal projections along with their projections on the picture plane always lie in a plane perpendicular to the corresponding trace of the picture plane, for example, point 3, 3^H, and the projection on the picture plane. If the picture plane *A-B-C* is held fixed and the *H* plane (horizontal plane) is revolved around trace *A-B* as an axis, 3^H has as its path the arc of a circle. The center of this circle lies on *A-B*, and the circle lies in the previously described plane, perpendicular to *A-B*. Likewise the revolved projections of all other points still lie in the same perpendicular plane in which they were located before revolution.

If the *H* plane is revolved into coincidence with the picture plane, the right angle appears in true size as shown by *A-D^r-B* in *Fig.* 4. Since the sides of the parallelogram in the original position were parallel to the x and z axes, the revolved positions are likewise parallel to *A-D^r-B*. Thus the revolved view becomes a scalable rectangular view and is exactly the same as the top view in *Fig.* 1.

Similarly, the *F* and *P* planes (frontal and profile planes) can be revolved, *Fig.* 5. Since the perpendicular relation of the points and picture-plane traces is constant, the original pictorial projections of the block may be omitted.

In *Fig.* 6 only the revolved projections are shown. Lines drawn from points on these views, perpendicular to the corresponding picture-plane traces, represent the edge views of plane loci of the projections of the respective points. Thus the intersection of the three perpendiculars from the revolved views of any point represents the orthographic projection of that point. An axonometric drawing could be made by using these intersections to find principal points of the drawing.

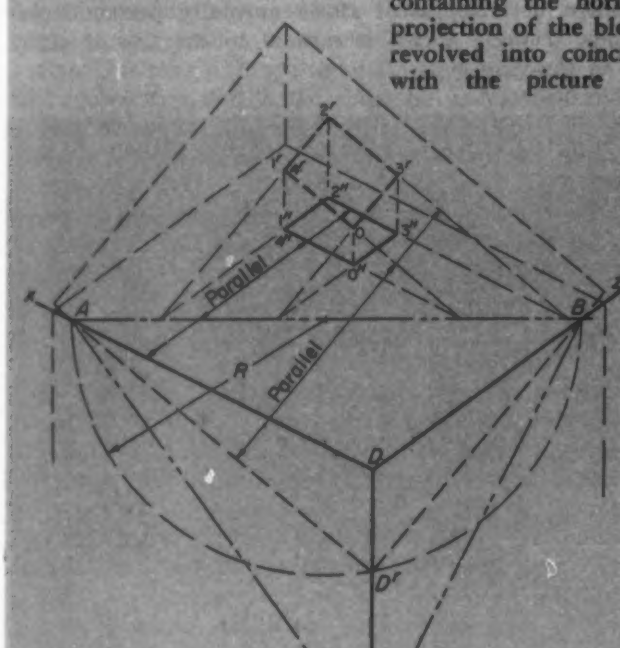


Fig. 4—Horizontal plane, containing the horizontal projection of the block, is revolved into coincidence with the picture plane

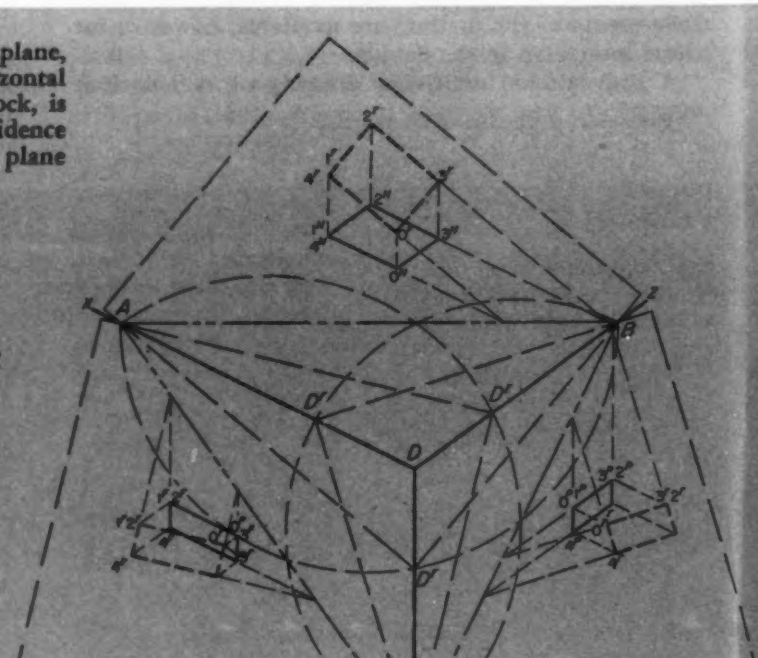


Fig. 5—Horizontal, frontal and profile planes are revolved into coincidence with the picture plane

Constructing an Axonometric Projection: To construct an axonometric projection a set of axes may be drawn in any position as long as none of them appear perpendicular. If all three axes were inclined equally to the picture plane, the resulting projection would be isometric, and the angles between any adjacent pair of axes would appear as 120 degrees. The resultant picture plane in this case is represented by an equilateral triangle. If only two axes are inclined equally, a dimetric projection results, and an isosceles triangle represents the picture plane. When all three axes are inclined unequally the resultant projection is trimetric, and the triangle scalene.

The three axes in *Fig.* 7 have been drawn at random, all unequally inclined. The picture plane is established by drawing *A-B* perpendicular to the *y* axis, and *A-C* and *B-C* respectively perpendicular to the *z* and *x* axes. By bisecting *A-B* and describing a semicircle with diameter *A-B,* the revolved position of the top view of the axes may be located. In the same manner, by bisecting *A-C* and *B-C,* the revolved positions of the front and profile views of the axes are found by similar construction. All three of these are combined in *Fig.* 8 and are used to orient the views and the projections to produce the trimetric projection of the bracket. Note that the principal lines in each view of the bracket are placed parallel to the corresponding revolved position of that view of the axes. Any two of these views may be located at random but care must be exercised in locating the third view. Projections from all three views of one accurately located point on the bracket, perpendicular to the corresponding picture plane trace, must meet at a point. When this condition is satisfied, as shown by point *K,* the projection may be completed rather mechanically by simply drawing lines from corresponding points on any two of the views perpendicular to the proper trace. Note that points *M, N* and *R* have been located by different combinations.

Perspective Projection: A general definition of perspective projection is usually stated very simply as:

> "The projection of an object upon a plane surface by means of rays, or projectors, which converge at a point *not* in the plane.

In keeping with the methods usually employed in solving three-dimensional graphical problems, and also the name "central projection" which is frequently applied to it, a more precise definition may be formulated:

> In any system of drawing using three mutually perpendicular reference planes, perspective projection is the projection upon a plane which does not pass through the origin by means of projectors (or rays) which do pass through the origin."

This may appear to contradict other more general statements, but is actually in complete agreement. For any properly drawn perspective, however con-

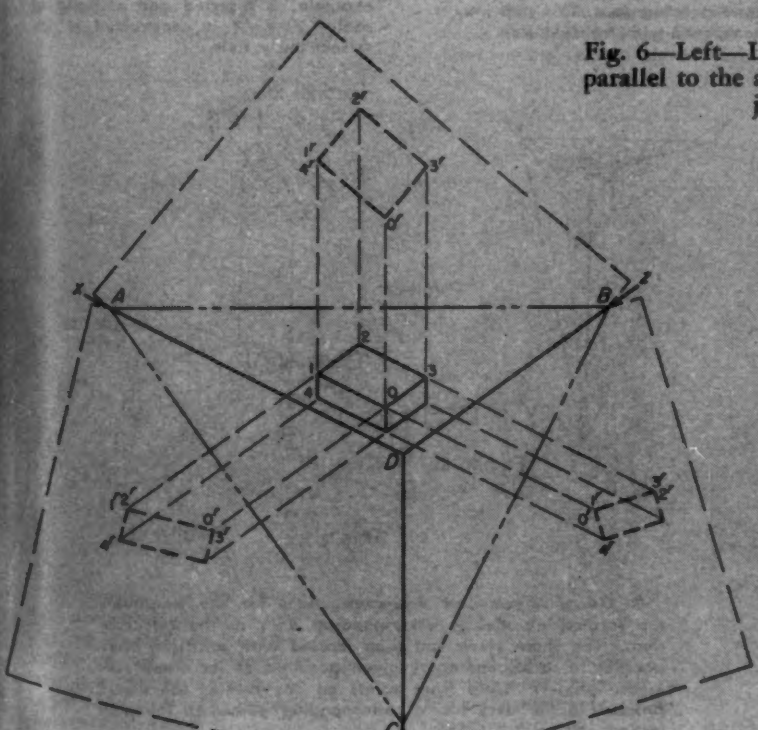
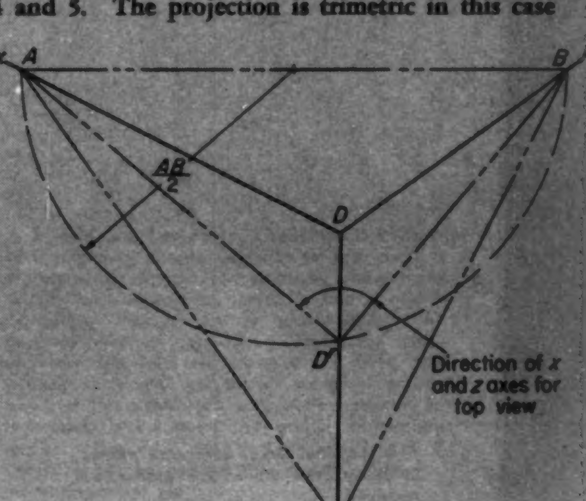


Fig. 6—Left—Lines from the three revolved views parallel to the axes establish the axonometric projection of the block

Fig. 7—Below—As a practical method, three axes and the picture-plane traces are established and the three planes are revolved as outlined in *Figs.* 4 and 5. The projection is trimetric in this case



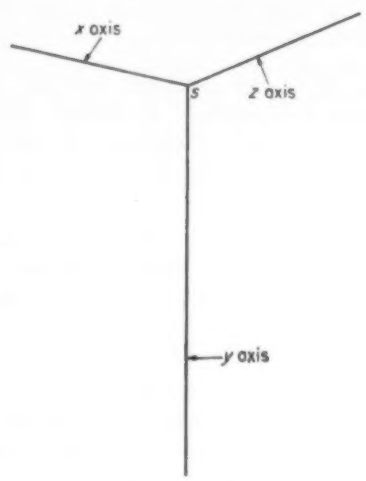
structured, a set of reference planes can be set up such that the point of sight is at the origin and the principal vanishing points will be on the axes common to those planes.

One advantage of this definition is that the entire subject can be reduced to a simple problem in descriptive geometry, and the fundamental operations more easily understood, since the basic construction employed is essentially the same as in the preceding coverage of axonometric projection.

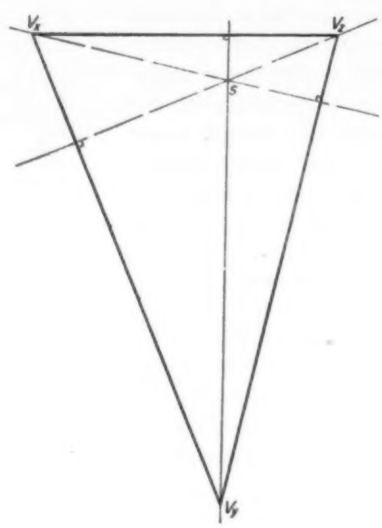
The transition from exact orthographic axonometric projection to perspective projection requires only two additional qualifications:

1. That the views (two or three) on the principal planes, which are used to produce the perspective, must remain in their respective position relative to the principal axes after revolution. A simple method of controlling this position is to place a

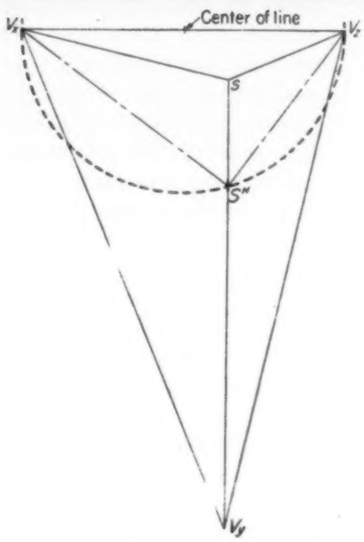
AXONOMETRIC DRAWINGS



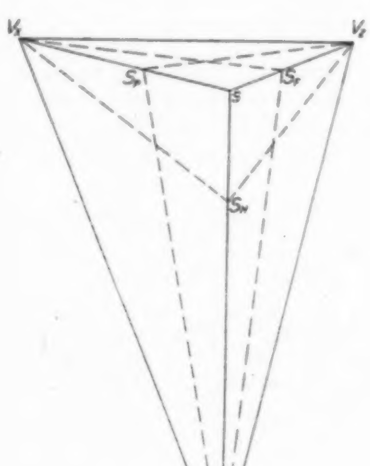
1. Establish Axes: Three axes, x y and z, are drawn, establishing three reference planes. If angles between axes are equal (120 degrees), the projection is isometric. If two axes are inclined equally, the projection is dimetric; and if all are inclined unequally, trimetric.

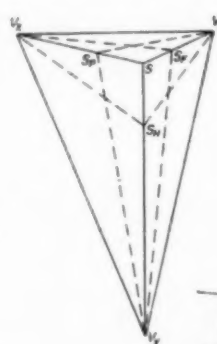


2. Locate the Picture Plane: Traces of the picture plane on the reference planes are drawn perpendicular to the corresponding axes. This step may be transposed with the first step.

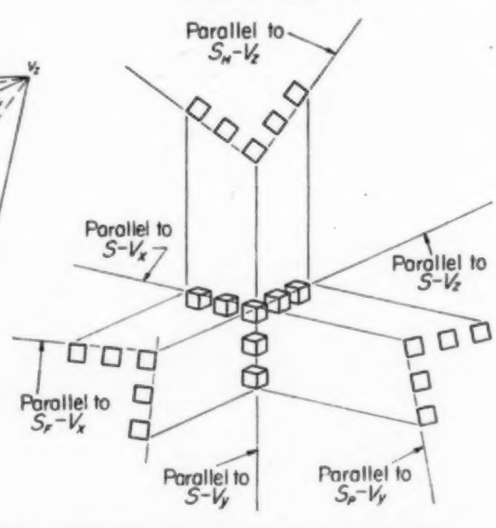


3. Revolve a Reference Plane: A reference plane is revolved into the picture plane. The trace, V_x-V_z for example, is bisected and a circle of radius V_x-$V_z/2$ is constructed to intersect the y axis.





4. Revolve Other Reference Planes: Similarly, the other two planes are revolved.



5. Orient Views and Projection: Axes for the projection are located parallel to corresponding axes in the construction. The three views are then located with principal lines parallel to corresponding revolved positions of the three reference planes. Lines from points on any two of the views parallel to the axes locate corresponding points on the projection.

prominent point of the object in the picture plane, and on the normal from the origin to the plane.

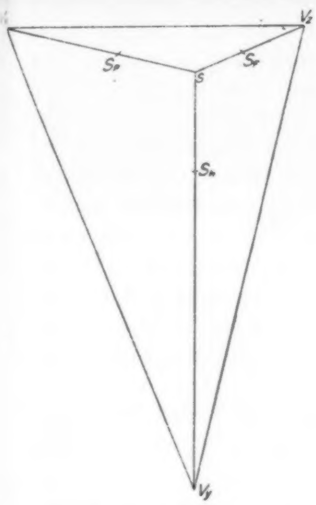
2. That all rays (projectors, lines of sight, etc.) shall converge at the origin (intersection of the principal axes).

In the illustrations that follow, the picture plane is represented by the triangle formed by its plane traces and is identified only by V_x, V_y, and V_z at the respective x, y, and z axis intersections. The reason for this

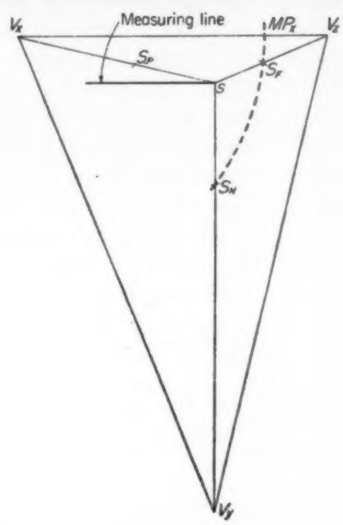
means of labeling these points will become apparent later when it is shown that these are the "vanishing points" for all lines parallel to those axes.

Basic Geometry of Perspective: The location of point 0 in the picture plane is illustrated in *Figs.* 9

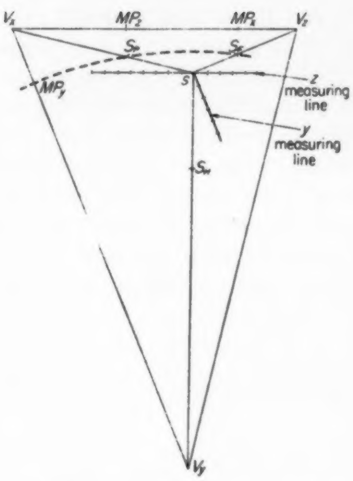
PERSPECTIVE DRAWINGS



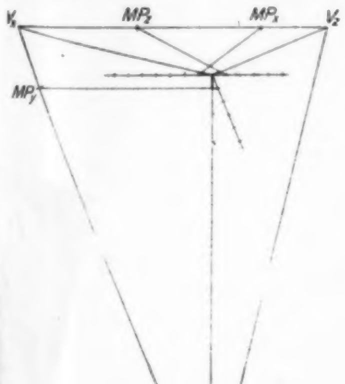
1. Establish Axes, Picture Plane and Revolved Positions: Follow steps 1 through 4 given under *Axonometric Drawings*. Several methods for handling vanishing points located outside drawing board edges are given in the text under *Practical Application*.



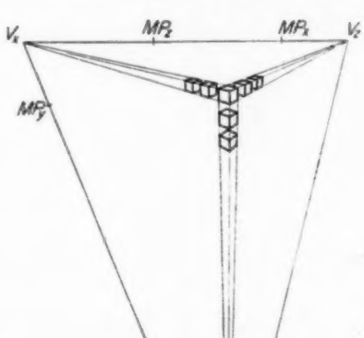
2. Locate a Measuring Point and Line: Measuring point MP_x for the x axis is established by swinging an arc of V_x-S_F (or V_x-S_H) radius to the V_x-V_z line. A measuring line is drawn from point S parallel to the corresponding picture-plane trace.



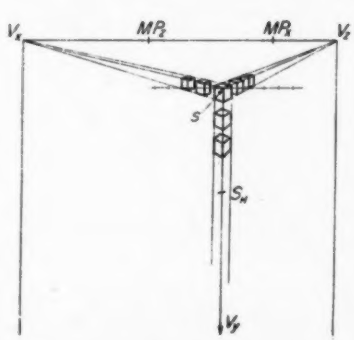
Similar measuring points and lines are established for the other axes. Location of y measuring point and line usually depends on proportions of the layout. Measuring lines are scaled off.



3. Measure Principal Points: Principal points on the projection are located on the intersection of the line extending from a measuring point to the scaled value with a line through the vanishing point.



4. Draw Projection: Connecting principal points just found establishes the perspective drawing.



5. One and Two-Point Perspective: If the picture plane is located parallel to one axis, a two-point or angular perspective (shown) results. For convenience, point S, and x and y measuring lines, should be placed below the horizontal picture-plane trace. True-scale measurements are laid off along the y axis, and vertical lines are all drawn parallel to this axis. If the picture plane is located parallel to two axes, a one-point or parallel perspective results. Similarly, the line of sight from S should again be oblique in order to utilize the measuring-point system.

and 10. A plane containing S (the origin), perpendicular to the picture plane and parallel to V_x-V_z, intersects the picture plane along line A-A' which is also parallel to V_x-V_z. The H projection of this line $a^{H'}$-a^H and a line through S perpendicular to V_x-V_z intersect to locate the projected position of 0 (0^H). By the same process 0^F and 0^P may be found.

In the pictorial drawing of *Fig.* 10 an oblique picture plane is represented by its plane traces. The projections of a rectangular block are also shown. This block has one of its corners 0 in the picture plane, on the normal from the origin. All of the edges of this block are parallel to one or another of the axes.

Since edge 1-2 is parallel to the z axis a plane may be set up to contain both lines. This plane is shown more clearly in *Fig.* 11, which is a "side" view of Fig. 10, by S-V_z-M. Rays from points 1 and 2, passing through the point of sight S, lie in this plane. Both rays intersect V_z-M which is the intersection of S-V_z-M and the picture plane. Likewise edge 1-4 is parallel to the y axis, and the vertical plane S-V_y-K can be set up to contain both. V_z-M and V_y-K represent the lines of intersection of these planes and the picture plane. They intersect at the point P which also lies on line 1-S and is the perspective projection of point 1. Another vertical plane may be set up to contain point 2 and the y axis. This plane will cut another line from the picture plane, and its intersection with V_z-M will locate the perspective projection of point 2. Other combinations of either one of these two planes and a similar plane containing the x axis may be used equally well by applying the same logic. *Fig.* 12 shows the layout of the first two planes in a conventional multiview arrangement and a study of this layout may help to clarify the principles.

Perspective Construction Theory: In *Fig.* 13 the revolved positions of the axes have been found in the same manner as outlined for *Figs.* 4 and 5. Since all rays converge at the origin, it has been marked S (point of sight) and the three revolved positions s^H, s^F and s^P. Note that these are revolved positions, but additional notation has been omitted for clarity. In order to locate the revolved positions of 0^H in this figure the line 0-A is drawn in the picture plane parallel to V_x-V_z. This is the line cut from the picture plane by a plane through S, perpendicular to the picture plane and parallel to V_x-V_z, as shown in *Figs.* 9 and 10. Locate a^H on the revolved position of the z axis, and the corresponding revolved position of 0^H. Here again the revolved positions are shown without being especially marked as such. The prerevolved projections which are the same as in *Fig.* 10 are marked as $a^{H'}$ and $0^{H'}$. Note that A-a^H is perpendicular to V_x-V_z, and that a^H-0^H is parallel to it. Draw 0-B and b^F-0^F parallel to V_x-V_y, and likewise draw 0-C and c^P-0^P parallel to V_z-V_y, thus locating all three revolved projections of point 0.

Using the three projections thus found, the three views of a rectangular block having edges parallel to

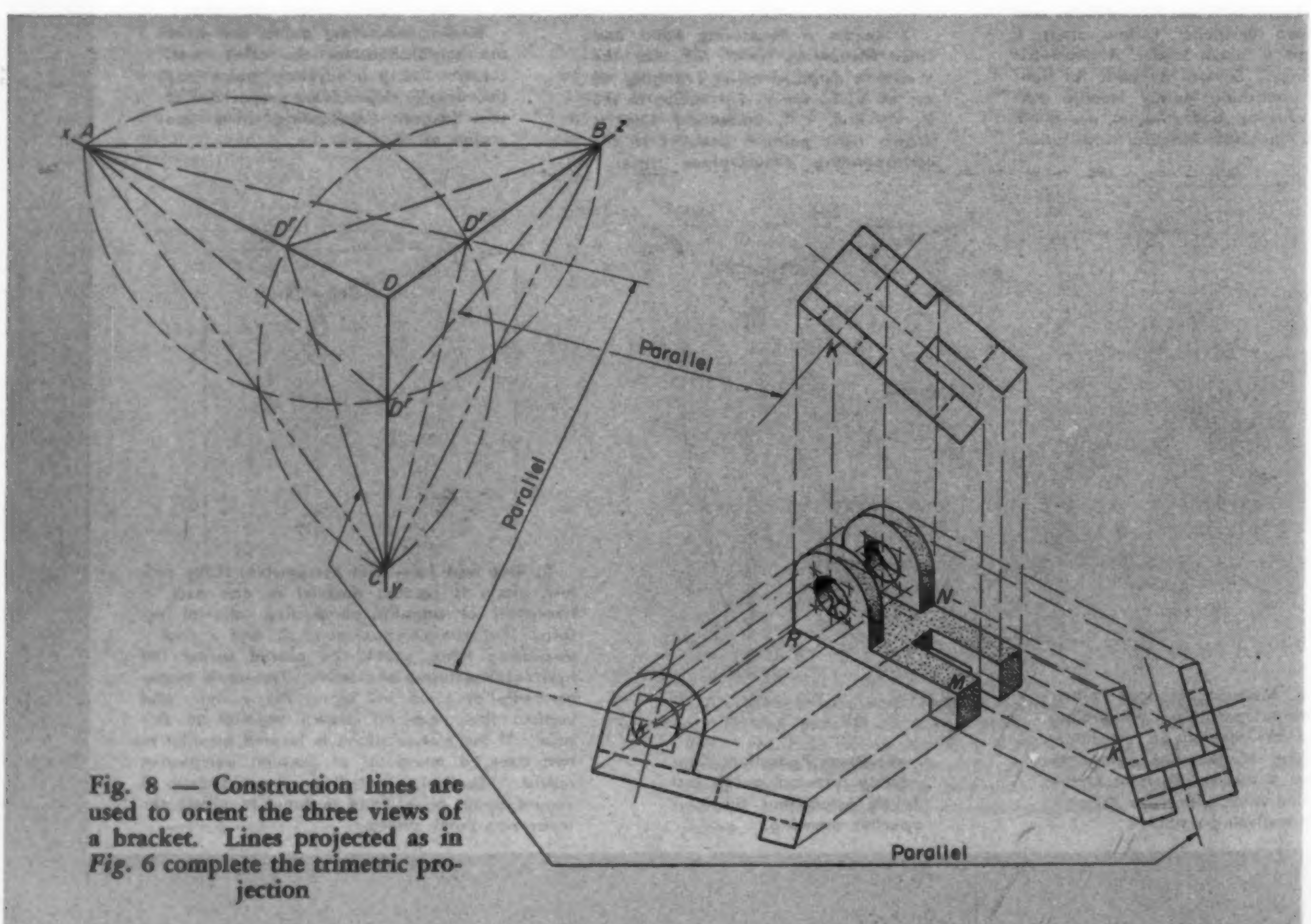


Fig. 8 — Construction lines are used to orient the three views of a bracket. Lines projected as in *Fig.* 6 complete the trimetric projection

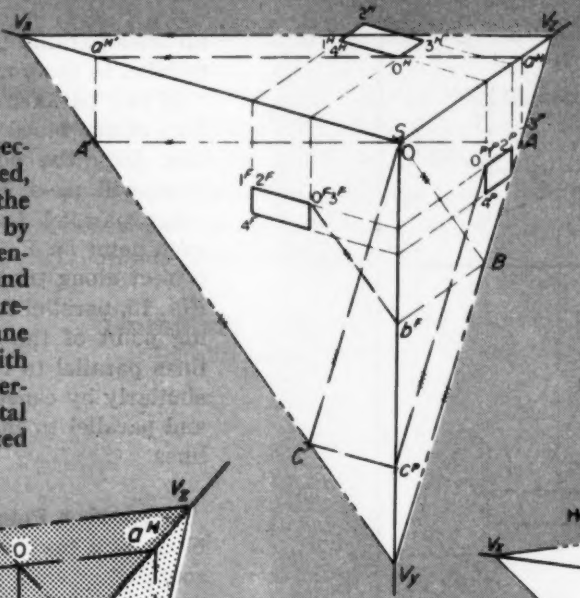
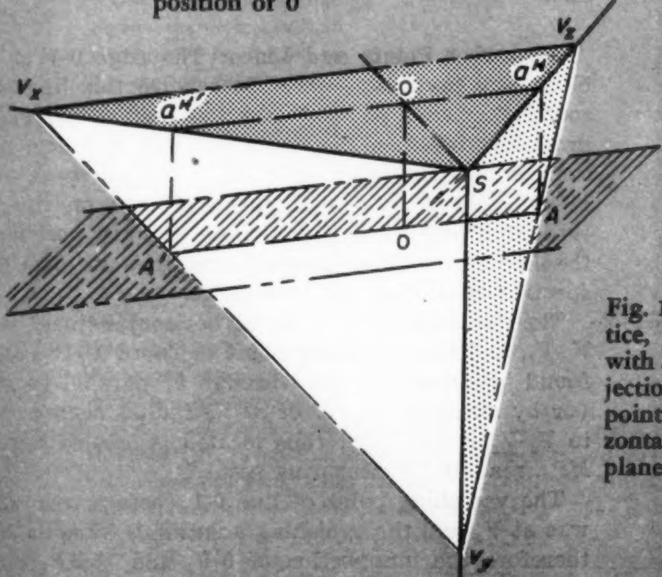


Fig. 9—Below—In the perspective-projection system outlined, the projection of point 0 on the horizontal plane is located by passing a plane through S perpendicular to the picture plane and parallel to the horizontal picture-plane trace. A vertical plane through the line intersection with the picture plane and a line perpendicular to the horizontal trace then locate the projected position of 0

Fig. 11—Below—Planes passed through a point on the projections and through the corresponding axis locate a point P on the picture plane which represents the projection of the point 1 on the original block



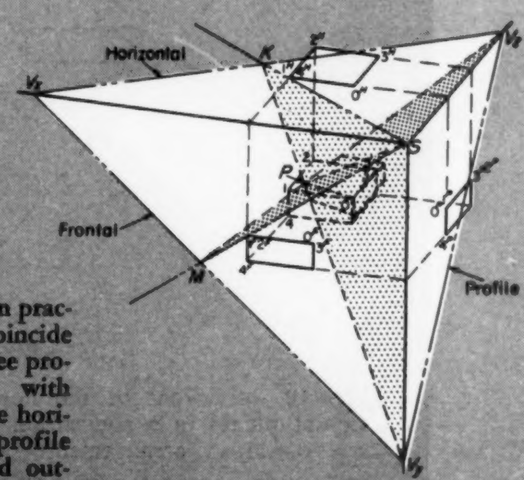


Fig. 10 — Above — In practice, point 0 must coincide with S. Only the three projections are shown, with point 0 located on the horizontal, frontal and profile planes by the method outlined in *Fig. 9*

the x, y and z axes are shown in their revolved positions in *Fig.* 14. This is the same as for any exact axonometric construction except that one corner of the block is placed at point 0 in the picture plane. The perspective projection of point 0 will coincide with S on the drawing, since point 0 is the foot of the normal from S to the picture plane.

To find the perspective projection on the picture plane of point 1 on this block draw s^F-1^F and extend it to locate point M on V_x-V_y. Also draw s^H-1^H and extend to locate point K on V_x-V_z. The line s^F-1^F-M represents the edge view of a plane perpendicular to the frontal plane, therefore containing the z axis. This plane is a locus of the perspective projection of point 1. The intersection of this plane and the picture plane produces line V_z-M which is a line locus of the projection. Likewise s^H-1^H-K is the edge view of a vertical plane containing the y axis, point 1, and the perspective projection of point 1. The intersection of this plane and the picture plane, line V_y-K, is another line locus. These two loci intersect, determining the perspective projection of point 1. A third plane through S, V_x and point 1, perpendicular to the profile, would likewise intersect the picture plane in a line passing through the same point.

By the same process, the projections of other points of the object on the picture plane may be found. In actual practice the construction amounts to a "scanning process." A series of planes containing an axis, each one passing through one or more significant points, is constructed; a second series of planes passing through the same points but containing a different axis then determines the perspective of the points.

Vanishing Points: The line loci of all perspective projection points on the picture plane are lines passing through the intercepts of the picture plane, as outlined in the previous paragraphs. It follows that the perspective projection of any line parallel to one of the axes will pass through the intercept of the picture plane on that axis. For example, line O-P on *Fig.* 11, which is the perspective projection of line 0-1 will pass through V_x. Thus the picture plane intercepts become the vanishing points of all lines parallel to the axes. In other words, the perspective projection of all lines parallel to the x axis converge at V_x. Likewise

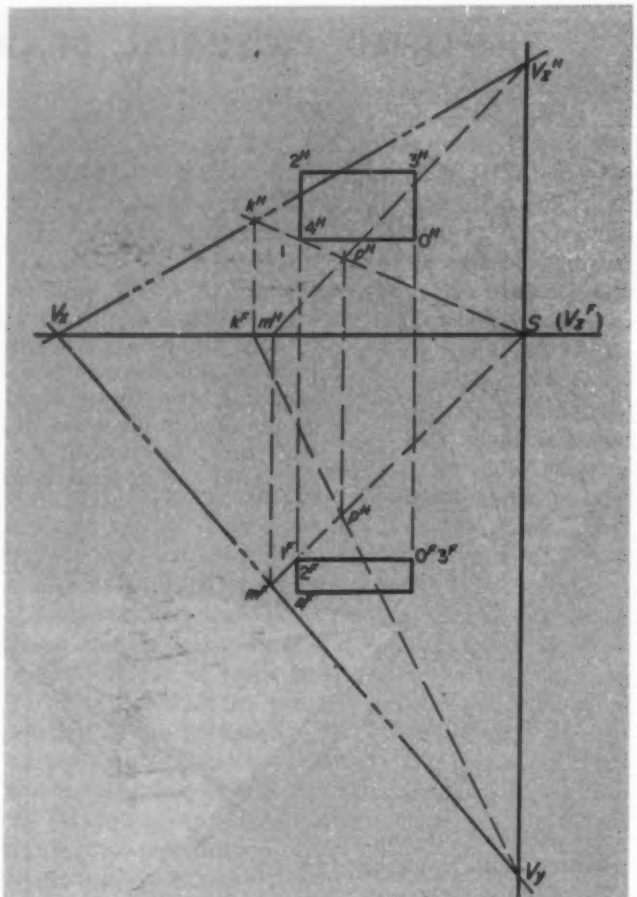


Fig. 12 — Layout of the horizontal and frontal planes in a conventional multiview arrangement

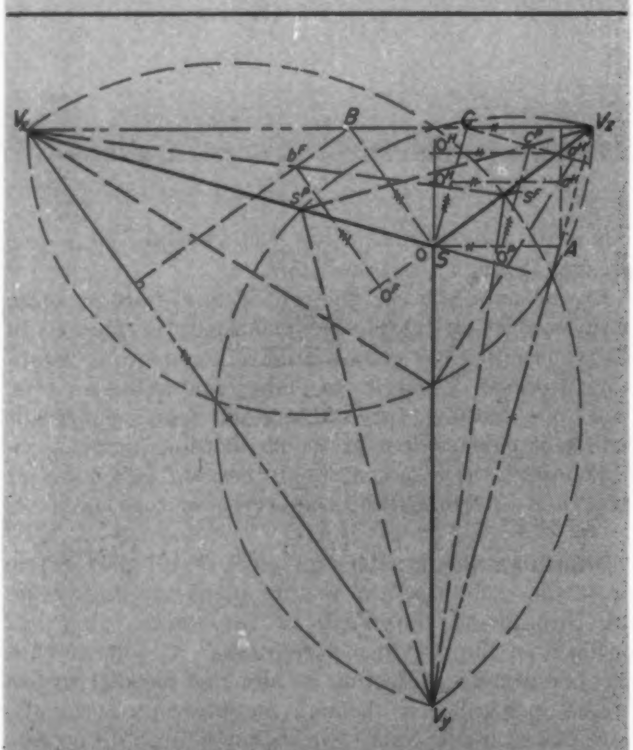


Fig. 13—Revolved positions of the three reference planes, similar to *Fig.* 7, help locate the revolved projections of point 0

all lines parallel to the z axis converge at V_z and lines parallel to the y axis converge at V_y.

If two parallel diagonals are drawn, one on the top face of the block 0-*W* on *Fig.* 15 and one on the bottom face, the perspective projections of these two lines will meet (vanish) at a point on V_x-V_z. All other parallel horizontal lines will vanish at some such point on V_x-V_z, and all horizontal planes will intersect along the same line. A line drawn from s^H in *Fig.* 15, parallel to 0^H-w^H, will cut V_x-V_z at the vanishing point of the diagonals. The vanishing points of lines parallel to the *H*, *F* and *P* planes may be found similarly by constructing a line through the view of *S* and parallel to the corresponding view of the inclined lines.

Measuring Points and Lines: The edge 0-1 of the block is a horizontal line. To revolve this line horizontally around point 0 into the picture plane, the projection 0^H-1^H in *Fig.* 16 is revolved to a new position of 0^H-1^r, parallel to V_x-V_z. The perspective of 1^r will fall at 1^s, directly below 1^r and on the line through 0 parallel to V_x-V_z. Since the new position of the line lies in the picture plane, it is its own perspective projection and is scalable.

The vanishing points of all horizontal lines lie on V_x-V_z, and the vanishing point of chord 1^r-1^H can be found by drawing a line through s^H parallel to 1^r-1^H (or by swinging an arc of s^H-V_x radius, center at V_x to V_x-V_z). The point thus located is labeled here as MP_x, read as "x measuring point."

The vanishing point of line 0-1 (before revolving) was at V_x and the vanishing point of 1^r-1^H is at MP_x; therefore the intersection of 0-V_x and 1^s-MP_x is the true perspective projection of point 1.

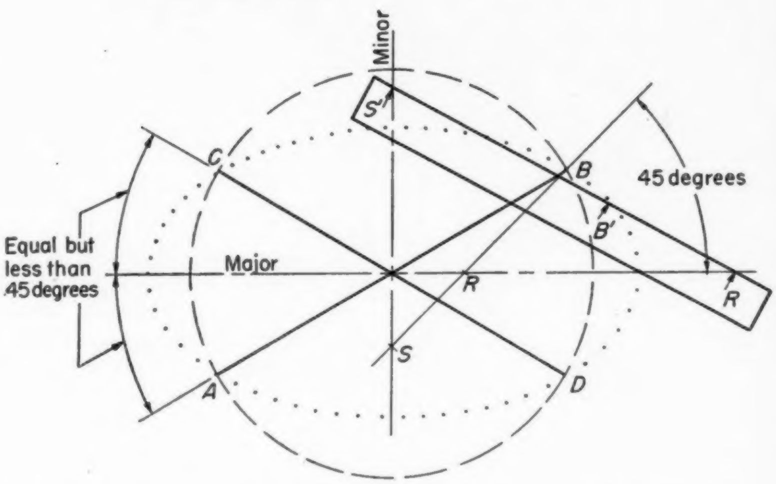
Measurements paralleling the x axis may be made along 0-1^s, which may be designated as the x measuring line. The projections of such points will be found at the intersection of 0-V_x and a line drawn through the point and MP_x (x measuring point). For example, a point k on line 0-1 will have its perspective projection at k' which is the intersection of k-MP_x and 0-V_x.

Likewise an arc having V_z as its center and V_z-s^H radius locates MP_z. A true-size scale may be laid out on a line through 0 parallel to V_x-V_z, *Fig.* 17. *X* dimensions behind the picture plane may be made to the left of 0 on this line, and the perspective of such points found on 0-V_x by means of a line from the point to MP_x. Likewise, z dimensions are made to the right, and their projections found on 0-V_z by connecting points on the scale with MP_z. An arc having V_y center and V_y-s^P radius may be used to locate a y measuring point MP_y on either trace. The y scale drawn through 0 must be parallel to the trace on which the measuring point is located. Measurements below the plane are taken downward from 0. The choice in the location of the y measuring point and line depends upon the proportion of the layout. Additional measuring points and lines for both x and y dimensions may be located parallel to the *F* and *P* traces respec-

METHODS FOR DRAWING CIRCLES

Ellipses are often drawn on isometric drawings by the familiar "W" or "four-centered" method. Although the method is easy, individual circles are not pleasing to the eye. And circles which are tangent in conventional three-view engineering drawings either intersect or miss completely when drawn as ellipses in pictorial views. The following methods eliminate both difficulties.

Isometric Ellipses
(Trammel Method)



Isometric circles, as well as dimetric and oblique circles with known conjugate diameters equal in length, can be drawn by this method. Ellipses made by this method will match template ellipses, but should not be used on a drawing containing ellipses drawn by the "W" method. According to usual practice, a pair of perpendicular diameters of the isometric circle are drawn, which serve as equal conjugate diameters. Major and minor axes are drawn to bisect the included angles. Line *B-S* is drawn from the end of either diameter to make an angle of 45 degrees with major and minor axes. A piece of stiff paper is then laid along this line and distances *B-R* and *B-S* are marked off as points *B'*, *R'* and *S'* on the paper to form a trammel. Points on the ellipse are then found by marking successive positions of point *B'* as *S'* and *R'* are shafted along the two axes. (See Reference 2.)

Perspective Ellipses
(Parallelogram Method)

The parallelogram method lends itself well to all forms of pictorial drawing, and is practically mandatory in drawing perspective ellipses. Each half of the longer conjugate diameter is divided into equal parts, and each half of the short sides of the enclosing parallelogram is divided uniformly into the same number of parts. Lines drawn from one end of the shorter conjugate diameter through points on the long diameter (*A*-1, *A*-2, etc.) intersect lines drawn from the other end of the same diameter to corresponding points on the end of the parallelogram (*B*-1', *B*-2', etc.). These intersections lie on the desired ellipse. In preference to dividers, the graphical method of dividing sides shown in area *BD* of the parallelogram should be used. In essence, two diameters are drawn, and parallels are erected at the intersection. The four smaller parallelograms are similarly divided, and so on. In perspective, all "parallels" and sides of the rhomboid are drawn through the proper vanishing points. Divisions will appear unequal in length, but are actually in the proper proportion.

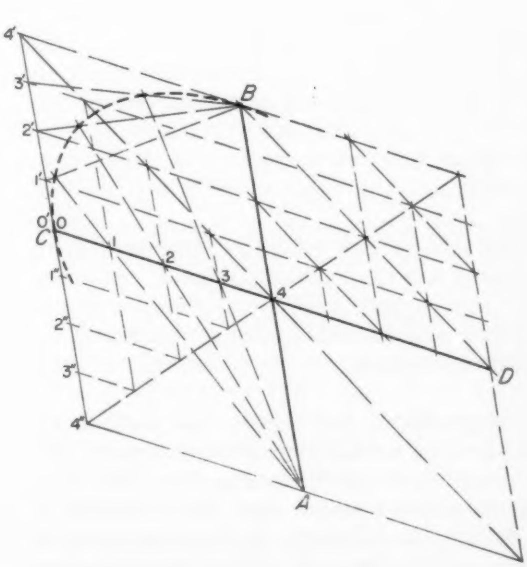
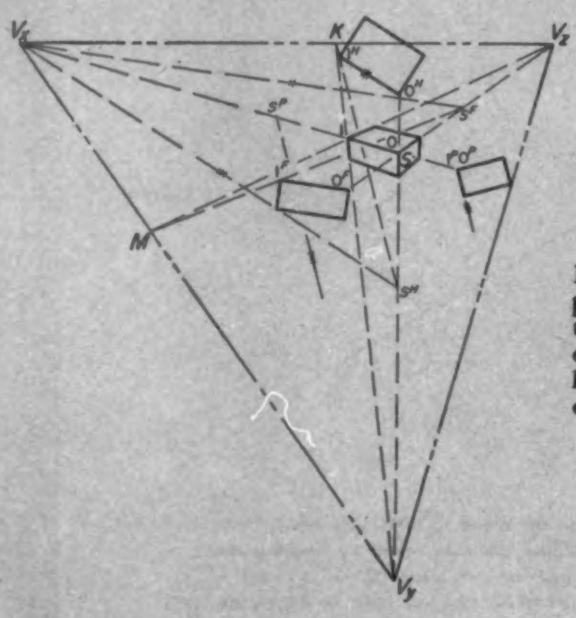


Fig. 14 — Below — Using the three revolved positions of point 0, three views of a rectangular block are drawn with edges parallel to the *x*, *y*, and *z* axes. Method of locating principal points on the projection is also shown, as are vanishing points at V_x, V_y and V_z



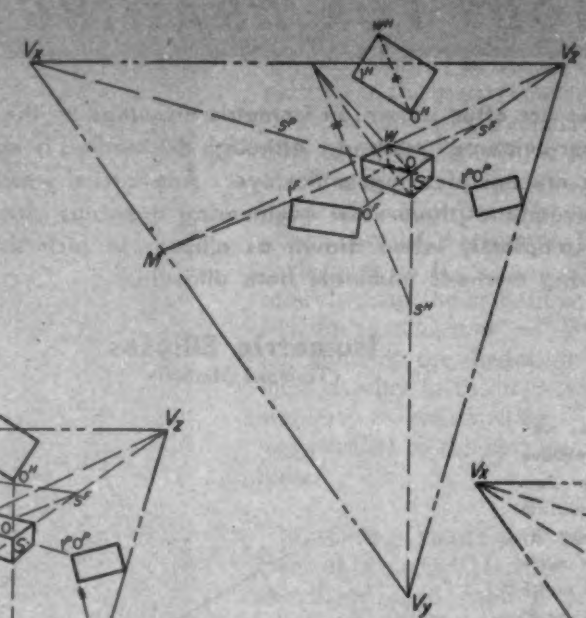
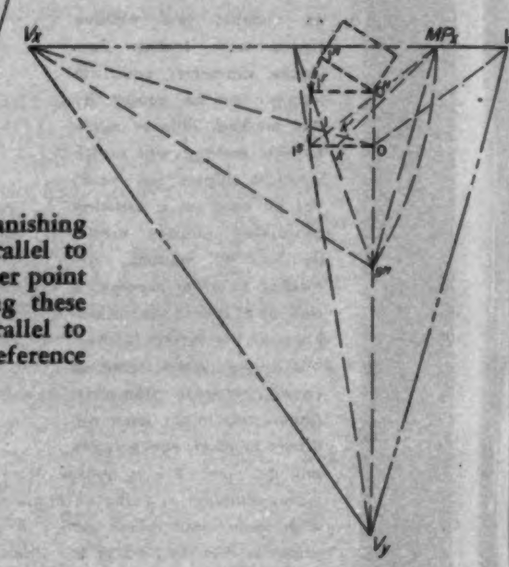


Fig. 15 — Above — Vanishing point of lines not parallel to the axes lie at some other point on the trace, providing these lines are in planes parallel to one of the three reference planes

Fig. 16—Below—To set up a method for making perspective measurements along the three axes, the horizontal projection of one of the horizontal lines in the block is revolved to a new position 0-1' parallel to V_x-V_z. An *x* measuring point MP_x is established by running s^H-MP_x perpendicular to 0-V_x. A line from MP_x to true-scale length 0-1' then establishes the perspective measurement 0-1



tively, but are usually not very helpful.

Measurements in front of and above point 0 can be made in the opposite directions, *x* dimensions to the right, *z* dimensions to the left, and *y* dimensions above 0. The same measuring points are used in either case, the result being that the measurements will be less foreshortened.

In projecting circles the simplest procedure is to project the center and the enclosing square. However distorted the square may become, the ellipse representing the circle may be satisfactorily constructed by the parallelogram method.

Practical Application: The layout and part of the construction used to produce the oblique perspective of a simple assembly is shown in *Fig.* 18. The cams on this assembly are circular and the construction to draw an ellipse representing a circle of their diameter, with center at 0, is shown. This "parallelogram method" is probably the simplest means of constructing perspective ellipses. Diameters of this circle were measured along the *x* and *y* measuring lines, as indicated by the circled points. Faces of the cams were located by points numbered 1 and 2 measured on the *z* measuring line. In each case these measurements were transferred to the proper axes by the method previously described. Other details of the construction are not shown, but follow a similar pattern.

It may be noted that all of the foregoing is based on an inclined picture plane with a significant point of the object being located in that picture plane at the foot of a normal drawn from the origin. The picture plane may, however, be made parallel to one or more of the axes. If the picture plane is made parallel to the *y* axis, that is, a vertical plane, the result will be an angular or two-point perspective. In this case it is more convenient to place point 0, and the *x* and *z* measuring lines at some point below the horizontal plane.

A *y* measuring point (MP_y) will be at the same elevation as point 0 and directly below either V_x or V_z. Since the plane in this case is parallel to the *y* axis, V_y is an ideal point an infinite distance away. All vertical lines are therefore drawn parallel, perpendicular to the horizontal trace of the picture plane.

If the picture plane were to be placed parallel to two of the axes the result would be a one-point or parallel perspective. Here again it is necessary that

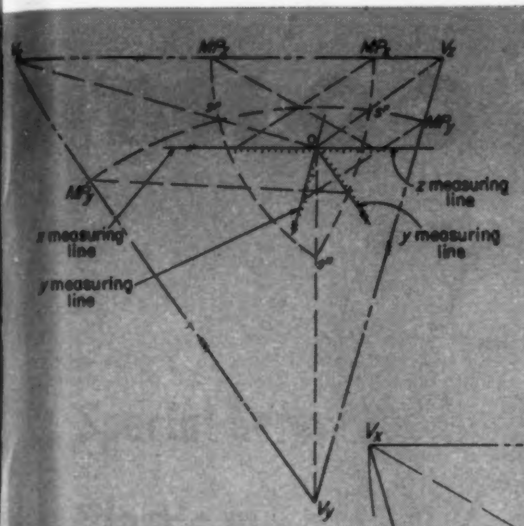
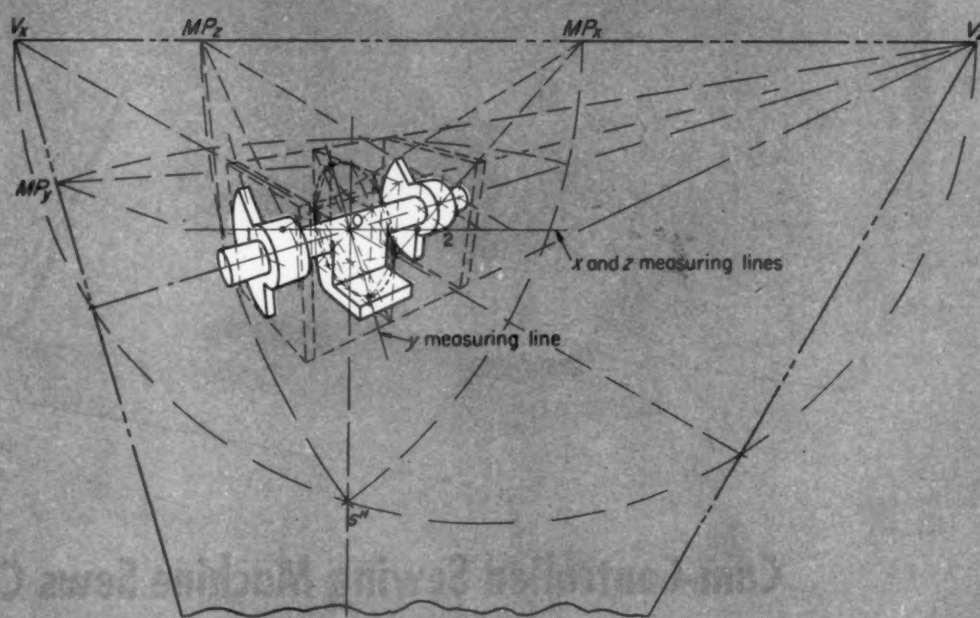


Fig. 17—Left—Complete system of measuring point and line constructions according to the system of *Fig.* 16. The *y* measuring line can usually be on either side of the vertical axis

Fig. 18—Below—Simple assembly drawn according to the perspective system outlined



the line of sight be an oblique line in order to use successfully the measuring point system outlined. However, in this case as well as in the case of the angular perspective, means may be readily devised to handle these measurements when making the "eye-level" perspective.

Several methods, as well as certain commercial devices, are available for handling vanishing points located outside the boundaries of the drawing board. One is to make a small layout graphically to test proportions, then calculate locations of vanishing points and measuring points by simple trigonometry, and use centrolineads for the actual drawing. Usually measuring points will stay within a reasonable distance.

If floor space is available, a surprising degree of accuracy can be obtained by stretching cords or thread from vanishing points located on adjacent drawing tables, etc. If a cord is stretched tightly, two points may be marked and a straightedge used to draw the desired line.

Still another method, which would be prohibitive if used for a complex object but is sometimes easier than physically locating the vanishing points, is to construct sets of lines through the vanishing points by Desargue's theorem. Two parallel lines are drawn to intersect adjacent picture-plane traces and sets of similar triangles are constructed using the parallel lines as bases. Lines joining the apexes of each set of triangles pass through the vanishing point.

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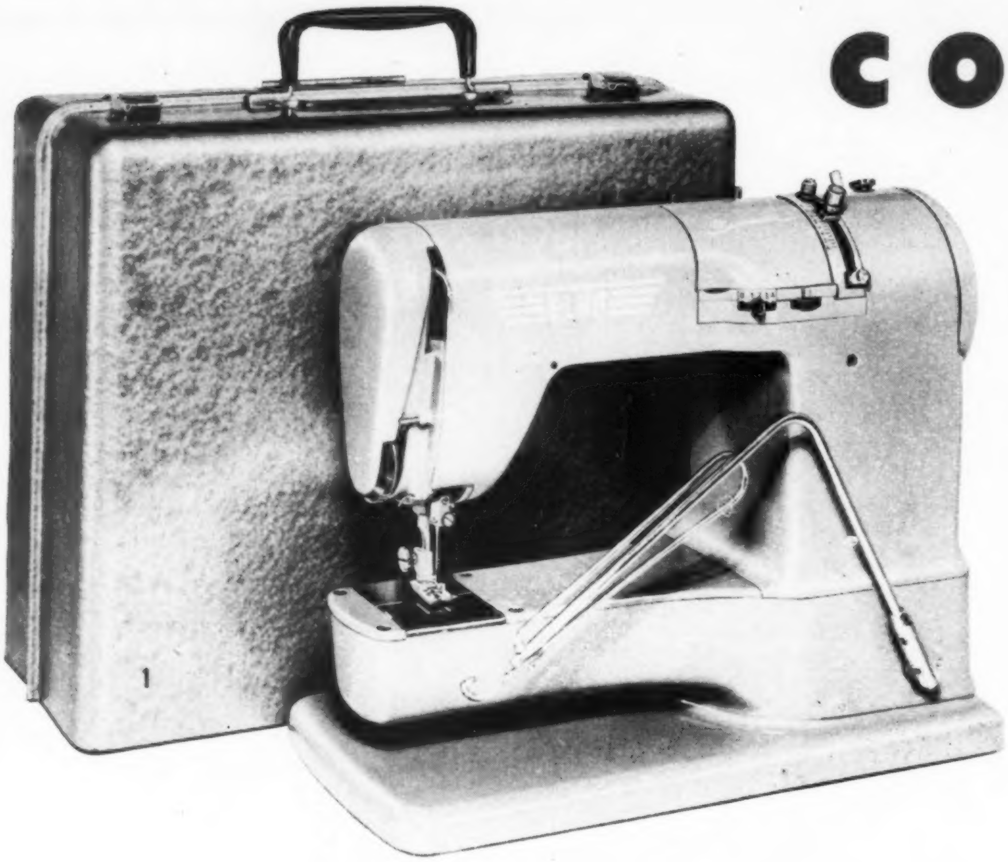
"Technology has brought the good life to the multitude. No respecter of class, it has benefitted the poor as well as the rich. It has done more to remove social inequality than all of the pious plans of the welfare state, than all of the good intentions of the dreamers in socialism. It is making it possible to realize the lofty goals that we have pursued, futilely at times, for so long. Thus we realize that material things can be used to serve exalted aims. Technology doesn't have to promote materialism. Rather it can help us to come closer to the spiritual objectives that we are seeking."—Dr. J. T. Rettaliata, *president, Illinois Institute of Technology.*

CONTE



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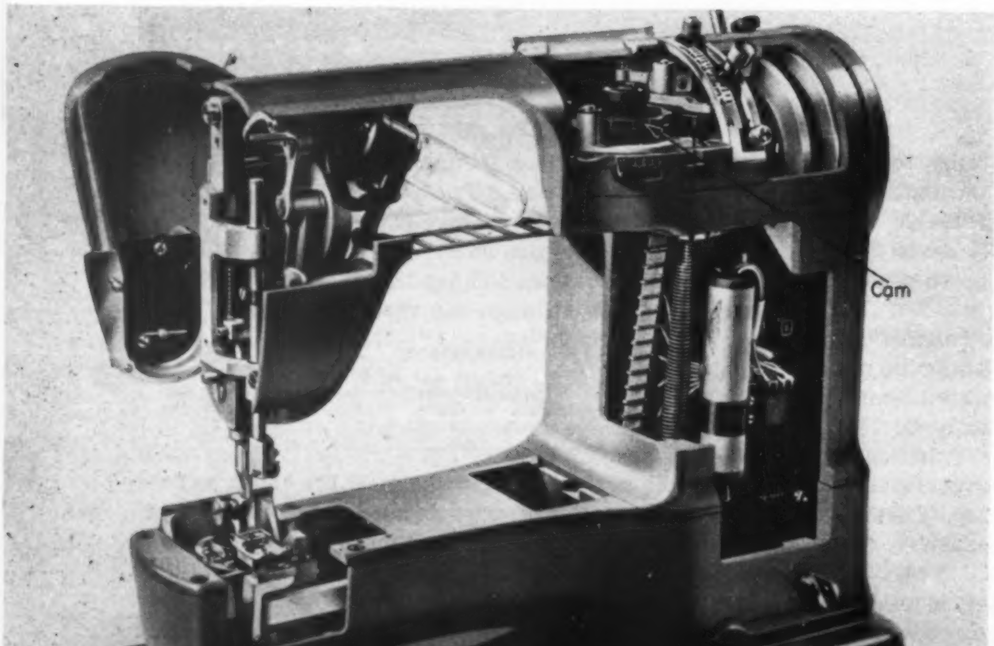
Cam-Controlled Sewing Machine Sews Complex Stitches



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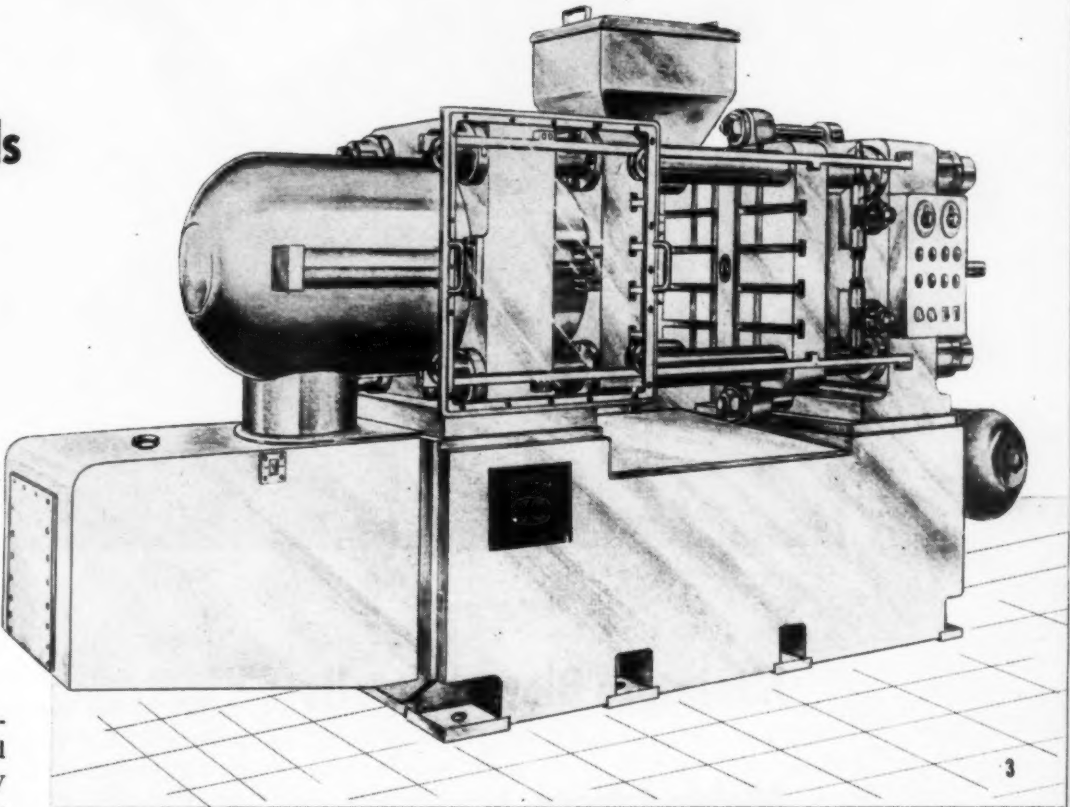
MANY different decorative stitches can be sewed on the Supermatic sewing machine, *Fig.* 1, by changing a double plastic cam. Without attachments, the machine can sew straight or zig-zag stitches, can sew on buttons, make buttonholes, or scores of different ornamental stitches.

The cam fits over a "turntable," *Fig.* 2, much the same as in a phonograph, and can be replaced in a few seconds. The top half of the cam controls sidewise motion of the needle bar, while the bottom half controls forward and backward movement of the feed points. A calibrated tension control permits adjustment of bobbin tension to match fabric thickness. Other features of the Swiss-made machine, which is imported by Elna Corp. of America Inc., include a twin needle clamp for sewing with two different threads at the same time, a built-in knee control, and a "free" arm for sewing sleeves, socks and items of a tubular nature.

Special Screw Feeds Plastic in Molding Press



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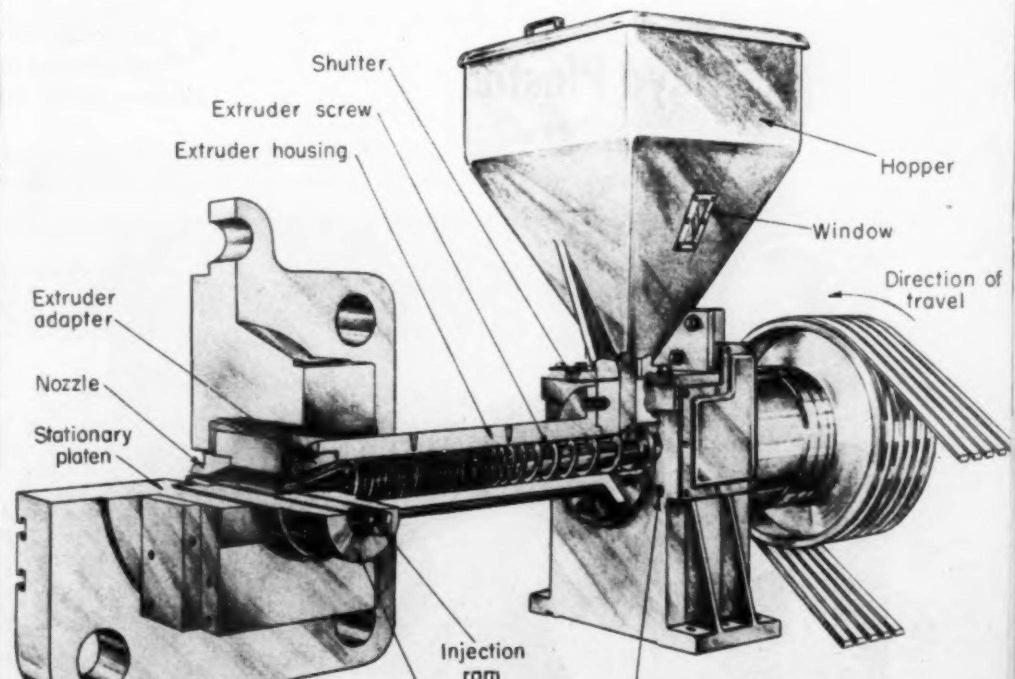
A SCREW with progressively decreasing pitch transfers plastic material from the hopper to the injection chamber in the 16-ounce horizontal injection press, *Fig.* 3. A thorough mulling action mixes and helps plasticize the material by frictional heat, although two 4-kilowatt electric heaters along the preplasticizer extruder housing, *Fig.* 4, provide most of the heat required. A third 4-kilowatt heater maintains constant heat in the injection chamber.

Nearly 180 pounds of styrene can be plasticized per hour in the 16-ounce press developed by the Jackson & Church Co. Material is kept from clogging the hopper at the in-feed end of the screw by water-cooling. After compression and heating in the preplasticizing unit, the material is extruded at constant viscosity into the injection chamber. Since a torpedo is not needed in the injection chamber for plasticizing, the entire 16 ounces of material are injected in every shot. Both the injection ram and clamping mechanism are hydraulically operated, without toggle mechanisms. The same preplasticizing method is used in the company's 6, 48, 72 and 200-ounce machines.



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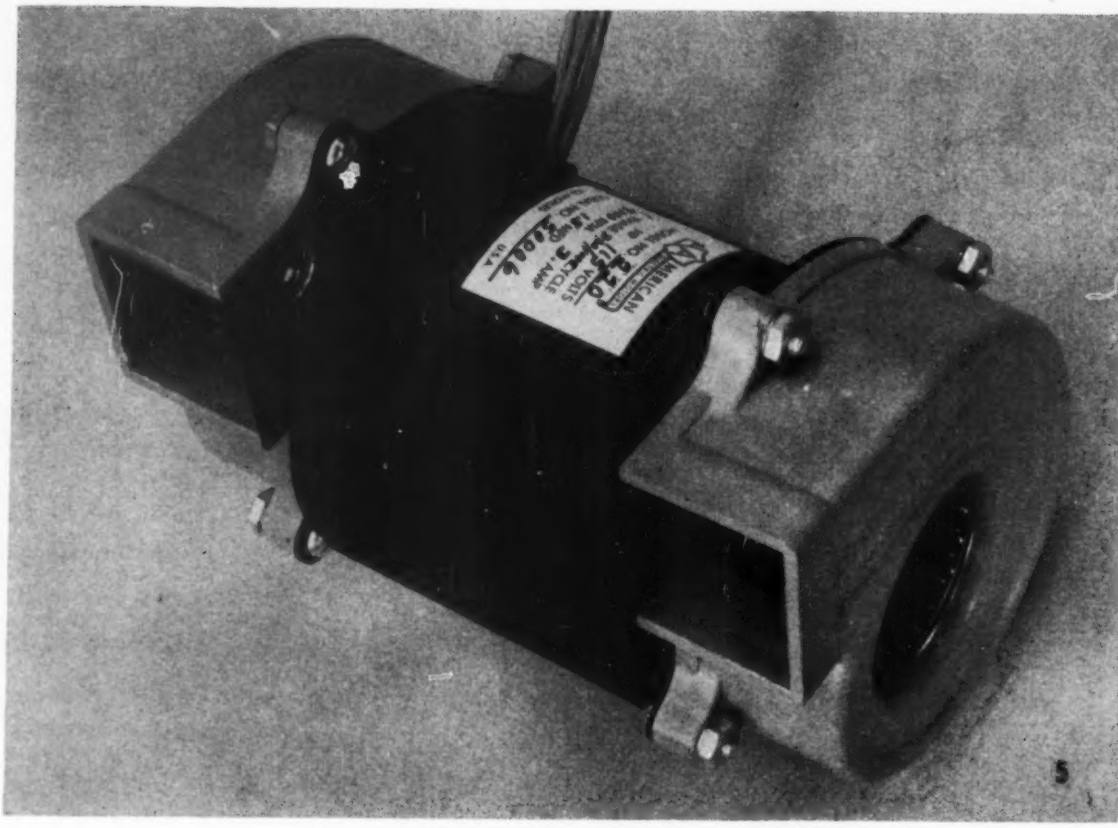
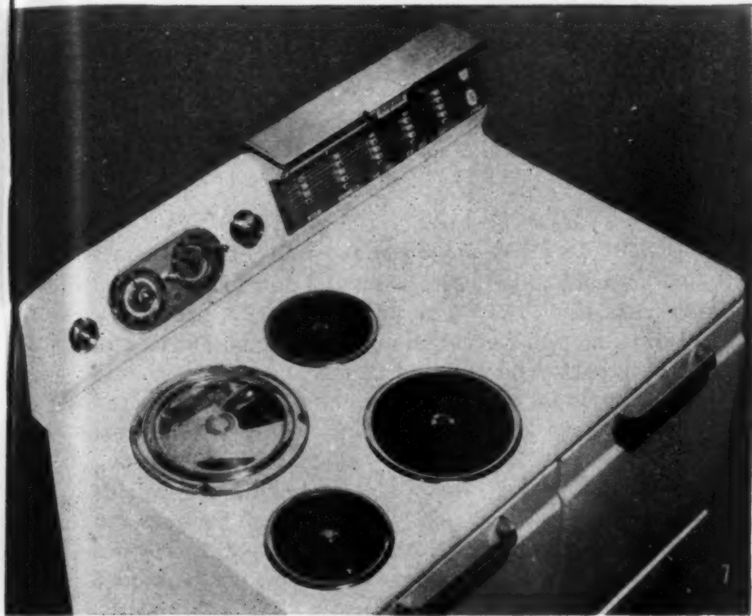
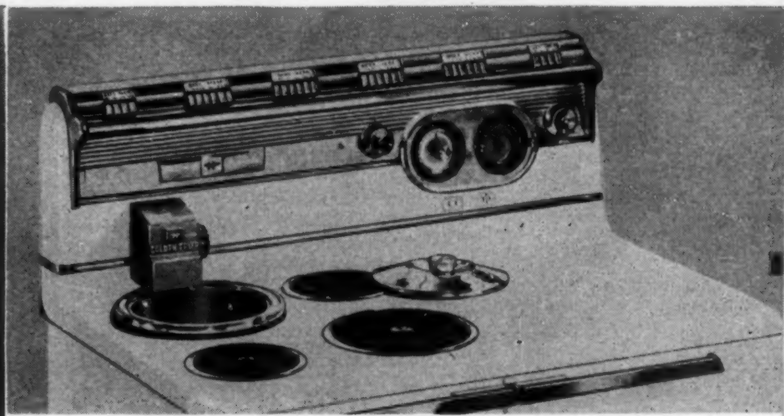


Miniature Blower Scrolls Molded from Alkyd Plastic

GLASS-REINFORCED alkyd plastic is used for weight reduction, high impact strength and good thermal shock resistance in the miniature blowers for cooling aircraft and electronic equipment, *Fig.* 5. Developed by Electroflow Pumps Inc., the blower housings resist temperature changes from −55 C to 125 C without crazing or being damaged. High strength of the molding material has made possible thinner scroll walls with consequent reduction in overall weight, has eliminated the need for metal mounting tabs, and has reduced breakage about 22 per cent in handling and assembly.

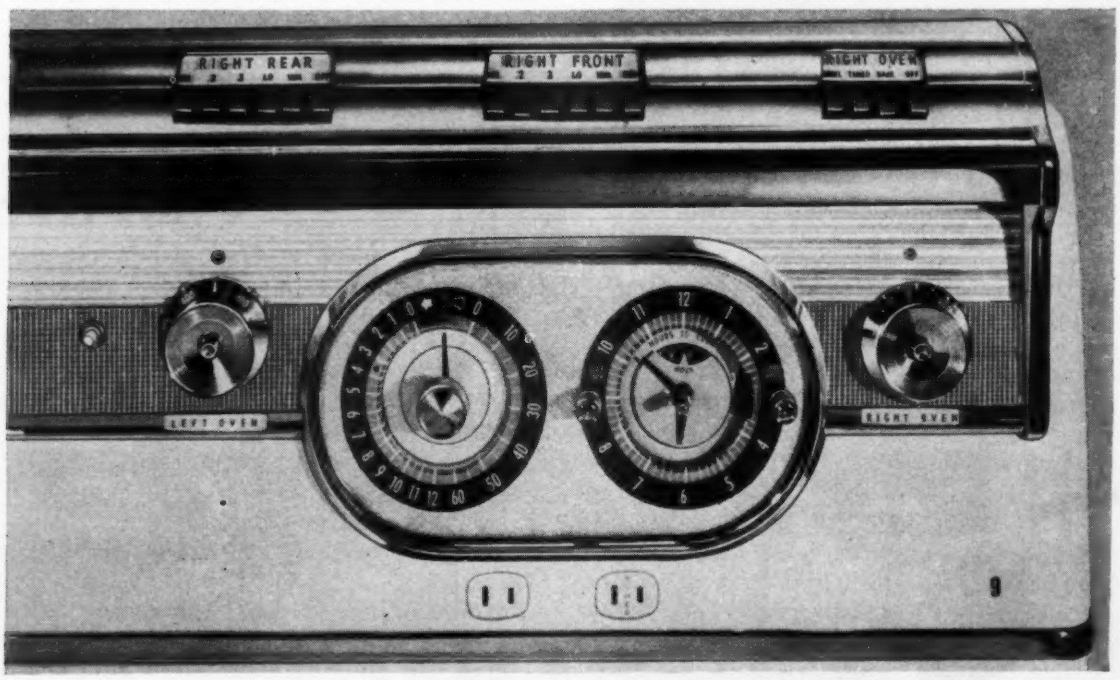
The blower assembly consists of a stamped aluminum back plate, aluminum or cadmium-plated Sirocco-type wheels and the scroll, which is transfer and compression molded of Plaskon glass-reinforced alkyd, *Fig.* 6, plus a miniature 400-cycle or variable-frequency electric motor. Blowers are supplied in 1½, 2 and 3 inch wheel diameters.



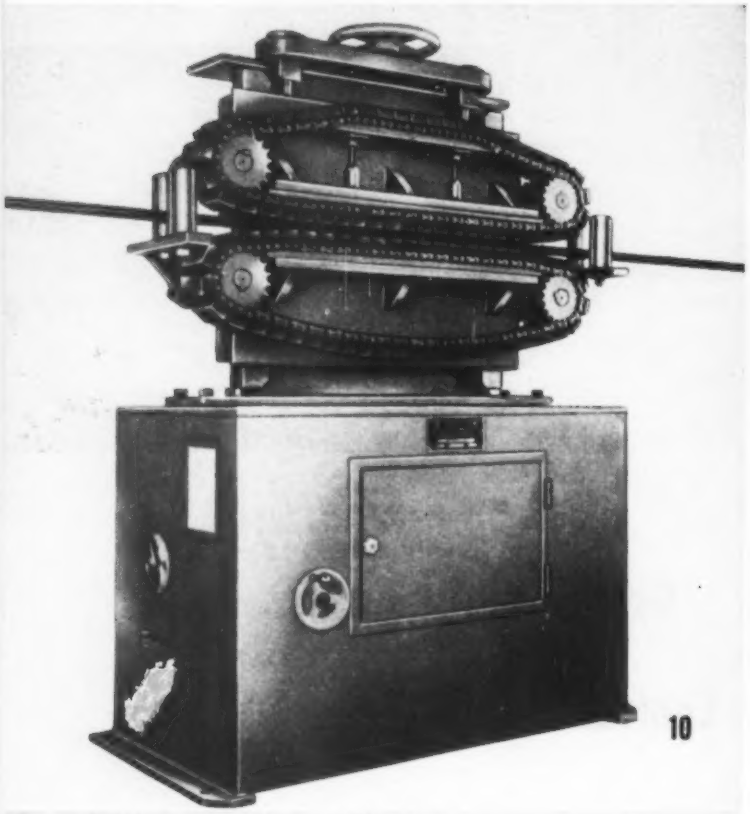


Grouped Pushbuttons Control Electric Ranges

PUSHBUTTON controls on 1953 Hotpoint Electric ranges are grouped for easy location, *Fig.* 7, on tilted-back panels. On several models, a "color key" system immediately tells which group of pushbuttons controls each surface unit, *Fig.* 8. A colored ceramic medallion in the center of each heating unit corresponds to a similarly colored pilot light in the pushbutton group. Oven temperature controls are grouped next to a minute timer and automatic hour-timing clock, *Fig.* 9. The whole cooking top and back panel overhangs the range body 1½ inches, permitting flush wall installation without removal of the baseboard.



Traction-Tread Machine "Pulls Out" Cable



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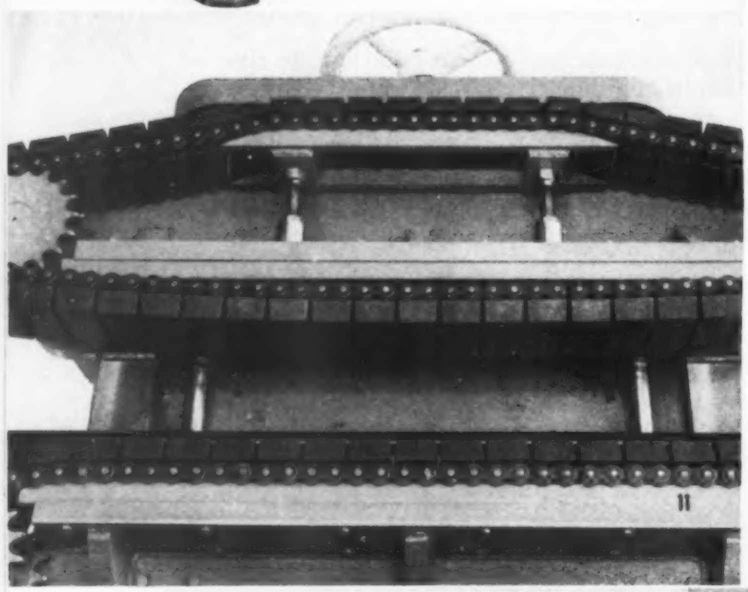
INCORPORATING an ingenious drive that permits adjustment of both treads up and down from a fixed cable centerline, the "Caterpuller," *Fig.* 10, provides a straight-line pull for cablers or stranders. Horizontal pull is imparted by traction treads consisting of a series of individual blocks molded of cork-filled synthetic-rubber tire stock. Each block is mounted between a dual-chain belt, with chain separator pins passing through the blocks. Hardened steel chain rollers ride on two hardened steel rails, *Fig.* 11, which back up and help guide the chain. Normal chain weight provides adequate tension on the lower tread, while a second adjustable dual rail supports chain weight in the upper circuit.

Drive of the James L. Entwistle Co. machine consists of a vertically mounted shaft, *Fig.* 12, driven through spiral bevel gears from a variable-speed mechanism. Two worms which drive the sprocket gears are mounted integral with this shaft, *Fig.* 13. Since centerline of the cable is fixed, distance between top and bottom pulling treads is adjusted equally from this fixed centerline through two parallel, vertically mounted screws by a handwheel. The two worm wheels merely rotate to a new position on the worm, thus distributing wear evenly and insuring perfect alignment of upper and lower tread blocks, since both wheels rotate an equal amount in opposite directions. An additional advantage is found in this drive method, since worm thrusts in opposite directions are all contained within the shaft and heavy thrust bearings are not necessary.



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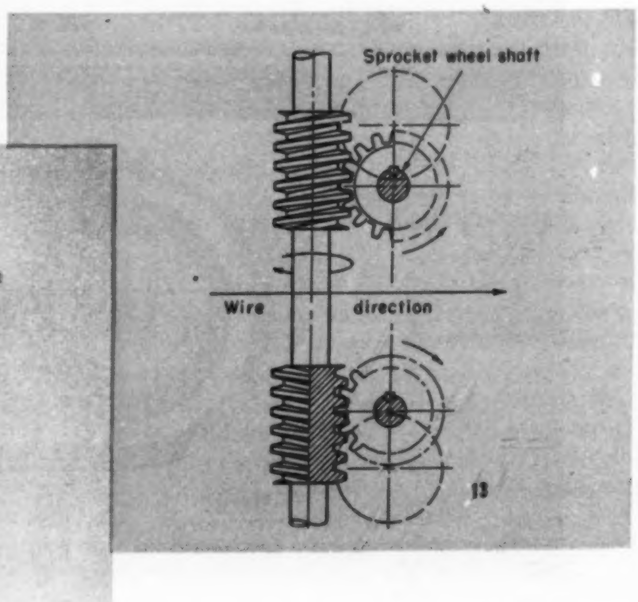

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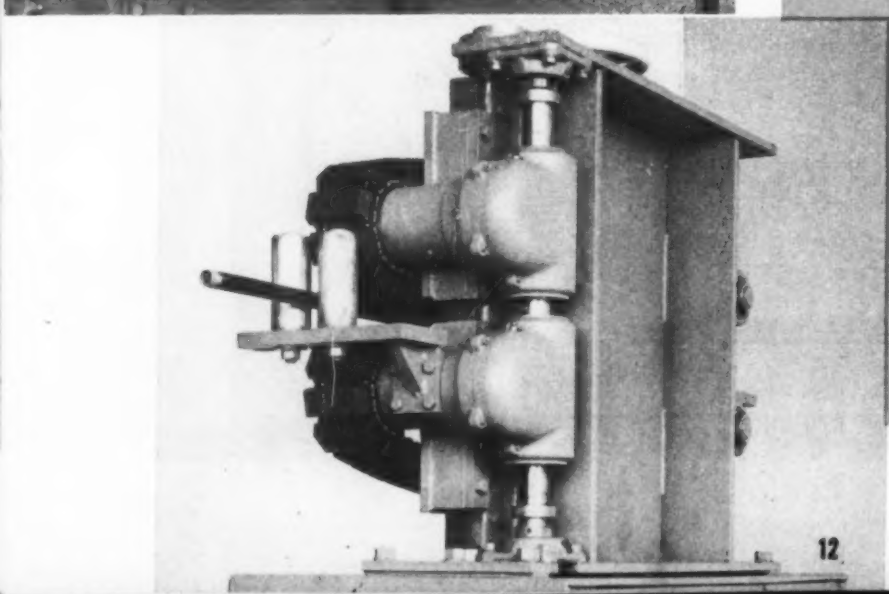

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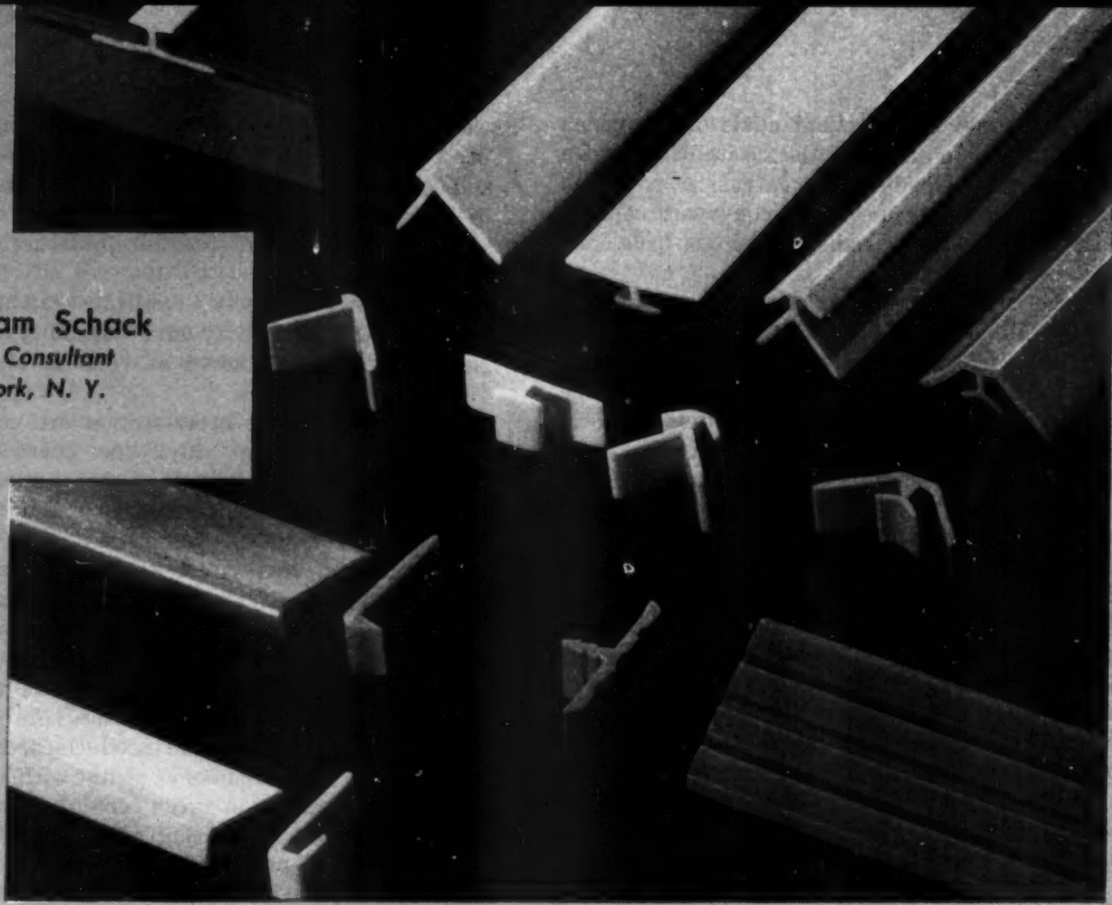

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PLASTICS EXTRUSIONS

CHIEF advantages of plastic extrusions are the economies possible because of low die cost and continuous production, relative ease of manufacture of the basic forms, and economical fabrication of these forms into finished components.

Extrusions take the form of rods, tubing (and similar enclosed, hollow shapes), sheeting, filaments, profiles (angles, channels, etc.), *Fig.* 1. Also extruded are coatings on wire, rope, pipe and wood. Not all of these forms have applications at present in the machine design field and the forms themselves indicate their permanent limitations. Since most of them are variable only dimensionally (for example, tubing in wall thickness and diameter), they cannot yield the number or diversity of shapes of, say, injection molding. This limitation is far less severe for extruded profiles, of which thousands of variations have been produced to specifications.

Often the extrusions need only be cut to size to be ready for use. These pieces can also be modified by bending, punching, heat-sealing, forming, shearing, drilling, tapping, etc. The operation may be performed by the extruder, or by the manufacturer who applies the extruded component. In any case, such a fabricated piece is usually far less expensive than if it were injection molded. Common examples are the nylon pinion and bushings shown in *Fig.* 2.

Processes and Materials: Today, extrusions are produced by the dry continuous process which is hardly more than 15 years old and already accounts for some 250,000,000 pounds of material annually. The earlier wet (or solvent) extrusion process is of little practical interest to machine designers, except perhaps that it is the means by which the strain-free polyvinyl butyral interlayer of safety glass is produced.

In the production of dry extrusions, *Fig.* 3, the material in granular form is fed from a hopper into the cylinder of an extruder. The cylinder has closely controllable temperature zones, and houses a screw which impels the material, rendered plastic by ap-

plied and frictional heat, toward a die orifice which has the approximate shape of the desired form. On emergence from the die, the extrusion is taken through a cooling medium by a conveyor, capstan or squeeze rolls with variable speed controls, and so assumes its final form.

All of the common commercial thermoplastics are now being extruded in this country: acetate, butyrate, ethyl cellulose, polyvinyl chloride and its copolymers, plasticized polyvinyl alcohol, polyvinyl butyral, saran, nylon, polyethylene, polystyrene and copolymers, and the fluorocarbons (Teflon, Kel-F). Silicone rubber is also being extruded.

Applications: Although plastics extrusions are of recent development, a considerable number of applications have already been found for them in various types of machines. Ethyl cellulose tubing has been used for the wands of vacuum cleaners, because of its toughness and resistance to abrasion. In the thickness required here, the plastic is quite rigid.

Flexible tubing has also found extensive employment. In a chemical-filling machine saran tubing, with its wide range of chemical resistance, high bursting strength and toughness, is used. In this machine both glass and porcelain piping had been used. Saran has greater shock resistance than either, and it has the additional advantage over porcelain of being translucent, which allows visual observation of liquid levels and possible obstructions in the line.

For another property—resilience—along with specific chemical resistivity and durability, vinyl plastic was selected to serve as rolls in blueprint machines.

Gaskets of diverse cross-section are cut from extrusions, particularly vinyl, the fluorocarbons and silicone rubber. In certain diesel engines, cylinder head gaskets of silicone rubber stand up under a temperature of 300 F. Also, because of their flexibility and compression set, they compensate for the gap varying from 1/32 to 1/16 inch arising from the accumulation of manufacturing tolerances for numerous metal parts.

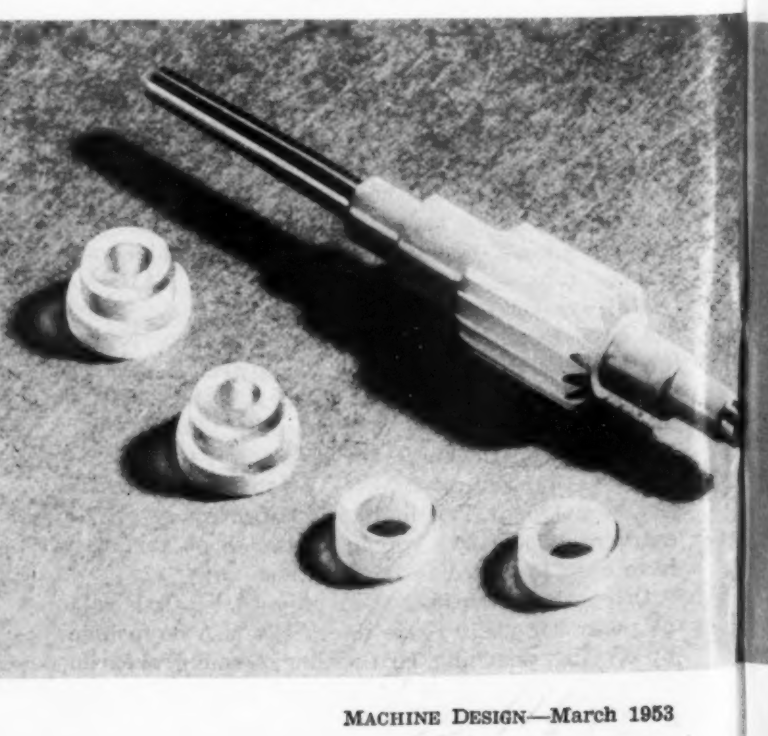
Extrusions other than sheeting are not usually fabricated by the forming process. An exception is a unit Schwab & Frank Inc. produce for Detroit Gear Co. to protect machinery parts with which they supply Studebaker. A large tube of acetate or butyrate is cut to size and a pair of ridges is then formed into the heated piece. The advantage of the fabricated tube over one formed from sheeting is that it is a closed shape. In a directly formed piece, the edges would have to be cemented together.

Sheeting in various thicknesses makes its appearance in diverse applications. Polyethylene film, cut to pattern and heat sealed, is used for electrically insulating television receiver picture tubes. In a heavier gage, 1/16 inch, this same plastic is used as a wiper blade which removes the excess face cream from jars in a filling machine which works

Fig. 1—Some varieties of tubing, rods and profiles produced by the extrusion process

Photo, courtesy Tennessee Eastman Co.

Fig. 2—Nylon pinion and bearings for a pressure-gage. Pinion is machined from a blank injection-molded directly on the metal shaft; bearings are machined from extruded rod stock



like a kind of waterwheel, *Fig.* 4. Polyethylene has proved to be more durable than the rubber wiper blade it replaced in this application.

The recently developed styrene copolymer sheeting (not all types of which are extruded), is one of the strongest of the thermoplastics, with good electrical and chemical properties as well. One fabricator has formed it into machine guards, replacing the sheet metal guards of his drill presses which had become badly damaged in use. Such guards might well be part of the original equipment. The same material is also finding application as covers and housings for appliances and business machines, not only because of its well-balanced properties but also because the forming process has become highly economical and permits an intricacy of design which would be much more expensive to implement in production by other methods.

No longer largely a hand technique, forming is now being carried out in fairly high-speed presses. The plastic sheets are heated in ovens adjacent to the presses to prevent cooling in the transfer, and they are sometimes pattern-heated to prevent undue thinning at some point and facilitate shaping at another. External and internal ribs, bosses, recesses, compound curves, can all be incorporated in the low-cost molds used in the process. These molds, commonly made of wood, can easily be modified in the course of the evolution of a design, relieving the designer of the anxiety of having to come up with a final product on his first try or face costly changes.

The open forms commonly called "profiles," including channels, angles, and the infinite variations possible, have been applied to the most diversified uses. The high-impact formulations of styrene developed in the last two years, with excellent chemical as well as mechanical properties, have led to their extensive adoption in breaker strips for refrigerators, *Fig.* 5. Vinyl profiles appear as bumpers for cleaners, sweepers and other machines. High abrasion resistance and resilience are the properties which match such applications.

One extruder has produced a ridged mounting and insulating ring of polyethylene for the screen end of a television picture tube. Although tubing, rods and other simple forms can readily be bent on heating, more intricate shapes cannot be bent beyond certain limits without distortion. This TV mounting ring is extruded in a continuous curve which can, in cut pieces, be readily bonded into perfect circular shapes.

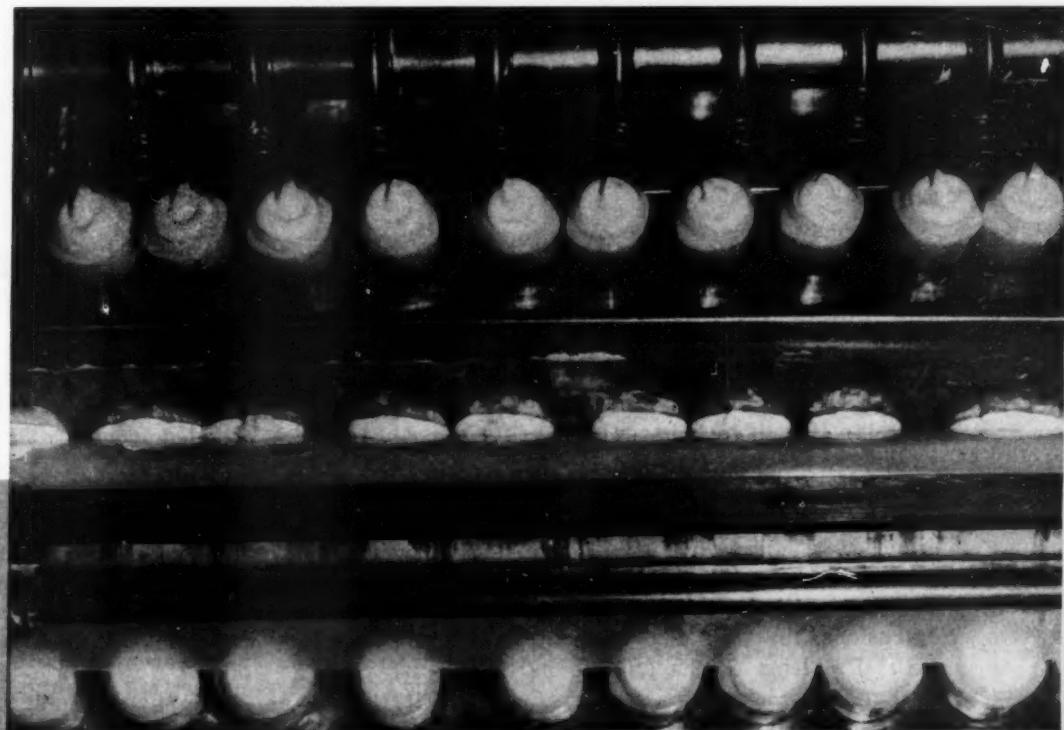
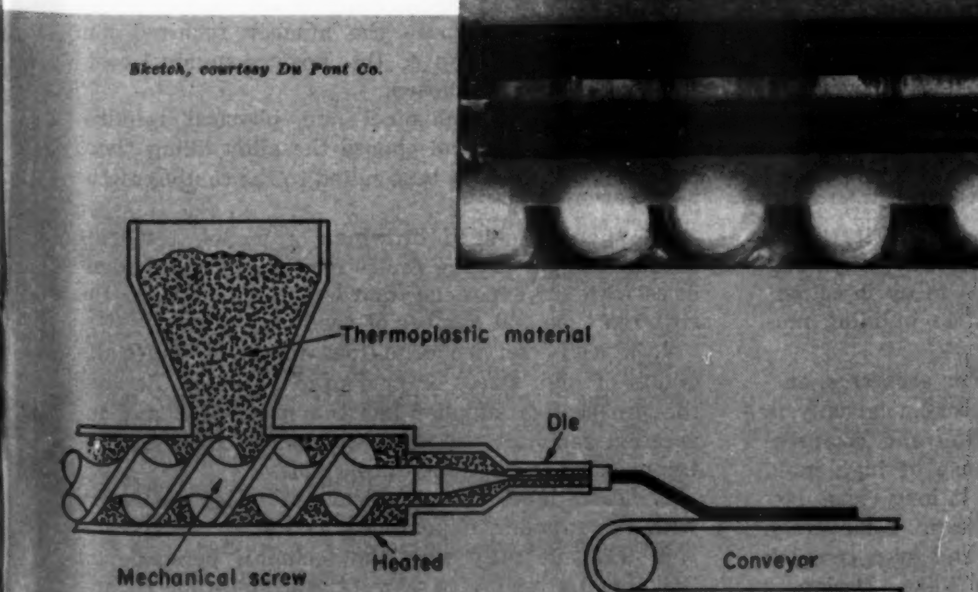
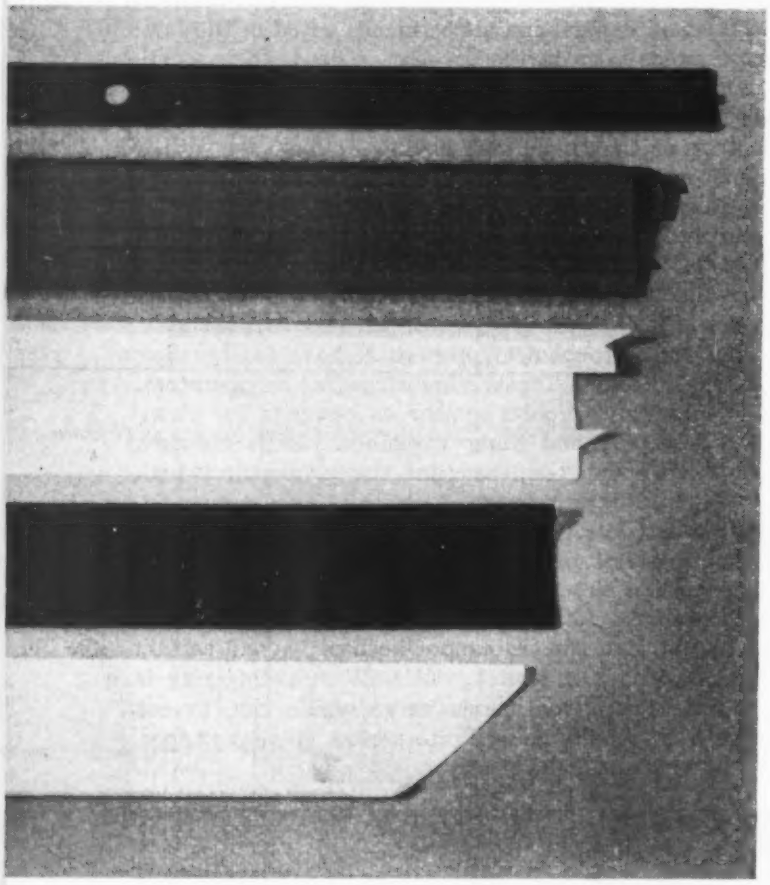


Fig. 4—Jar-filling machine showing polyethylene sheeting, cut into strips, serving as wiper blades to remove excess material

Fig. 3—Schematic diagram of the plastics extrusion process





Photo, courtesy Schwab & Frank Inc.

Fig. 5—A variety of extruded refrigerator breaker strips

Elliptical and other curved forms are also possible up to a maximum diameter of 3 feet.

Butyrate coatings are extruded on iron pipe, which is then cut and bent to shape for use as bus stanchions, rails and similar parts. In like manner, extruded coatings provide corrosion prevention, a pleasing surface, and color for safety or other purposes.

Design Considerations: In the foregoing applications references have not been made to "plastics" tubing or "plastics" sheeting, but always to a specific plastic. Choice of the right plastic for a given application is as important in extrusions as in moldings by other processes. The designer familiar with the latter should have no difficulty in working with extrusions, for they have virtually identical properties. Problems of the finished parts are also quite similar. For example, skimping on wall thickness is as false an economy in an extruded ethyl cellulose vacuum cleaner wand as it is in an injection-molded ethyl cellulose bobbin used in braiding machines.

Like plastics parts molded by other processes, custom-made plastics extrusions are economical only in sizable production runs. In injection and compression molding, this fact is so because of high mold costs, which can only be amortized in long runs. Extrusion dies, however, are quite cheap. An average sort might run from $50 to $100, and even complex dies would seldom cost more than $300. Designers may therefore sometimes allow themselves the luxury of a custom extrusion for the sake of a minor degree of added efficiency or improved appearance, when a standard extrusion would be adequate.

But low tooling cost is offset in important measure by set-up costs. Great as the technical progress has been in plastics extrusion, it is still far from a foolproof self-adjusting process. Because of relatively high set-up charges, a short run is not economical and is not called for unless the part desired cannot be produced by any other process. A safe rule of thumb is that if the weight of the parts to be ordered is about 500 pounds, the price will reflect the economies of the process. Runs under that amount will be, inversely, proportionally higher.

For all the delicacy of die adjustment required, extrusions are now being produced with a high degree of uniformity of dimension and to close tolerances. In typical commercial tubing specifications, for instance, tolerances vary from ± 0.002-inch for a wall thickness of 0.012-inch in tubing of 0.022-inch nominal ID to ± 0.010-inch for a wall thickness of 0.060-inch in 2-inch pipe. These are the figures on stock tubing. Closer tolerances can be achieved on these as well as other forms, but at a higher cost.

One authority holds that the extruder should maintain the following values:

Dimension (in.)	**Tolerance** (in.)
1	$\pm \frac{1}{64}$
1 to 3	$\pm \frac{1}{32}$
3 and over	$\pm \frac{1}{32}$ to $\pm \frac{3}{64}$

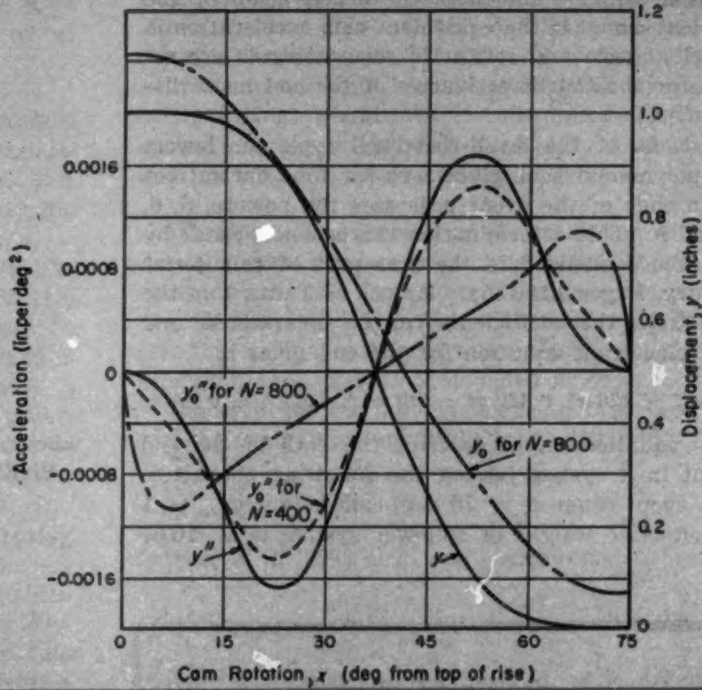
If plastics meet performance requirements, plastic extrusions warrant the designer's attention as a possible path to reduced cost.

Specifying Aluminum Castings

BETTER aluminum castings may be obtained if certain steps are followed in specifying requirements to the supplier. The following rules were abstracted from the winter issue of the *Aluminum Bulletin*:

1. Carefully estimate the number required and the rate of production so the most economical casting method can be chosen.
2. Determine mechanical and physical requirements of the part and choose the alloy filling these requirements which is best suited to the casting method.
3. Submit detailed drawings, a model, test pattern or sample casting for estimates to several foundries with the experience and facilities to furnish the required type and number of castings.
4. Specify service conditions in detail, especially points of high stress or pressure tightness. Be sure the prospective supplier has the production and inspection facilities necessary to assure consistent attainment of the specified properties.
5. Investigate the experience of other customers with the supplier, if possible.
6. Consult fully with the technical personnel of the supplier and give careful consideration to any changes they suggest to simplify production, reduce cost or produce better castings.

Fig. 1—Some characteristics of a dwell-rise-dwell 5-6-7-8-9 polynomial equation profile. Acceleration y'' of the end element is compared with equivalent cam accelerations y_0'' for systems having design speeds of 400 and 800 rpm. Equivalent cam displacement y_0 requires an entry ramp at the 75-deg terminus if y_0 is not to fall below end element displacement y at any point



How cam functions can be built on polynomial equations and how clearances and deflections in cam systems can be anticipated in design were discussed in two preceding articles. This final article summarizes the "polydyne" procedure by detailing the design of an actual automotive cam. Additionally, vibration is discussed and the principles of ramp design are presented.

POLYDYNE CAM DESIGN-III

By David A. Stoddart

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DYNAMIC aspects of cam design presented earlier under this subject have shown why the motion of the follower at the cam is not the same as the motion of the mass at the end of the follower linkage. Clearances, elasticity of the system, inertia forces, and return spring load contribute to deviations in cam command and end mass response. These influences generally can be analyzed and taken into account during design.

In this article, the effects of these dynamic factors upon cam design and operation will be discussed, and a specific example will be developed to demonstrate the practical application of the "polydyne" approach.

DRD Systems: In the second part of this series (February, Pages 146-154), the important relationship between the fourth derivative of the end element displacement and the equivalent cam acceleration was stressed. These terms are related through the second derivative of the basic equation

$$y_0 = y_r + \rho y + \phi y''$$

where y_0 = the equivalent cam displacement, y_r = ramp displacement, y = end element displacement,

$$\rho = \frac{k_0 + k_1}{k_0}$$

$$\phi = 0.093 \frac{w N^2}{k_0}$$

k_0 = spring rate of linkage system, k_1 = rate of re-

turn spring, w = effective weight of follower system, and N = rotational cam speed.

Since the second derivative of end mass displacement (acceleration) appears in the equation for equivalent cam displacement, the fourth derivative of the end mass directly influences the acceleration of the equivalent cam. If the equivalent cam acceleration is to start at zero and return to zero, controls are required for the fourth derivative of the end mass displacement.

For cams of the dwell-rise-dwell type, the lowest order polynomial that gives zero for four derivatives at both ends of the event possesses the powers, 5, 6, 7, 8 and 9. This determination can be easily made by the methods outlined in the first part of this series (January, Pages 121-135). By use of TABLE 1 in the first article, the coefficients can be determined, and the displacement equation for the end mass is

$$y = 1 - 126\,x^5 + 420\,x^6 - 540\,x^7 + 315\,x^8 - 70\,x^9$$

This equation might describe the path of the end element in a system having the following characteristics: event range x_r = 75 deg, cam height y_{max} = 1 inch, effective weight of follower system w = 16.67 lb, spring rate of follower linkage k_0 = 15,500 lb per in., and rate of return spring k_1 = 620 lb per in. Then, $\rho = (15{,}500 + 620)/15{,}500 = 1.04$ and $\phi = 0.093(16.67)N^2/15{,}500 = 0.0001\,N^2$.

Acceleration of the end mass is

$$y'' = -\frac{5(4)(126)}{(75)^2}\left(\frac{x}{75}\right)^3 + \frac{6(5)(420)}{(75)^2}\left(\frac{x}{75}\right)^4 - \frac{7(6)(540)}{(75)^2}\left(\frac{x}{75}\right)^5 + \frac{8(7)(315)}{(75)^2}\left(\frac{x}{75}\right)^6 - \frac{9(8)(70)}{(75)^2}\left(\frac{x}{75}\right)^7$$

$$= -0.448\left(\frac{x}{75}\right)^3 + 2.24\left(\frac{x}{75}\right)^4 - 4.032\left(\frac{x}{75}\right)^5 + 3.136\left(\frac{x}{75}\right)^6 - 0.896\left(\frac{x}{75}\right)^7$$

where $x/75$ = decimal part of the event range.

Similarly, the fourth derivative of the end mass is

$$y^{iv} = -0.0004779\left(\frac{x}{75}\right) + 0.0047787\left(\frac{x}{75}\right)^2 - 0.014336\left(\frac{x}{75}\right)^3 + 0.0167253\left(\frac{x}{75}\right)^4 - 0.0066901\left(\frac{x}{75}\right)^5$$

This investigation might be conducted for two speeds, N = 400 and 800 rpm. Then, $\phi = 0.0001\,N^2$ = 16 and 64, respectively. Pertinent resulting curves are shown in *Fig.* 1

The curve for end mass displacement y is calculated, of course, from the basic 5-6-7-8-9 polynomial. End mass acceleration is plotted from the foregoing equation for y''. Acceleration of the equivalent cam is calculated from the second derivative:

$$y_0'' = \rho y'' + \phi y^{iv}$$

That is, $y_0'' = 1.04\,y'' + 16\,y^{iv}$ for N = 400 rpm and $y_0'' = 1.04\,y'' + 64\,y^{iv}$ for N = 800 rpm, where y''

Fig. 2—Demonstration of deflections in a spring-return cam and follower system

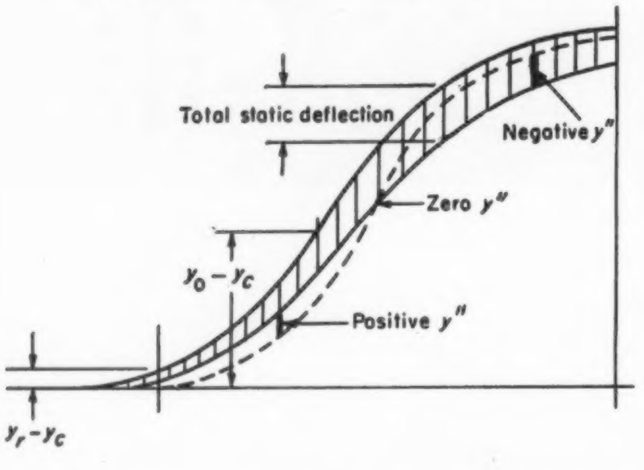
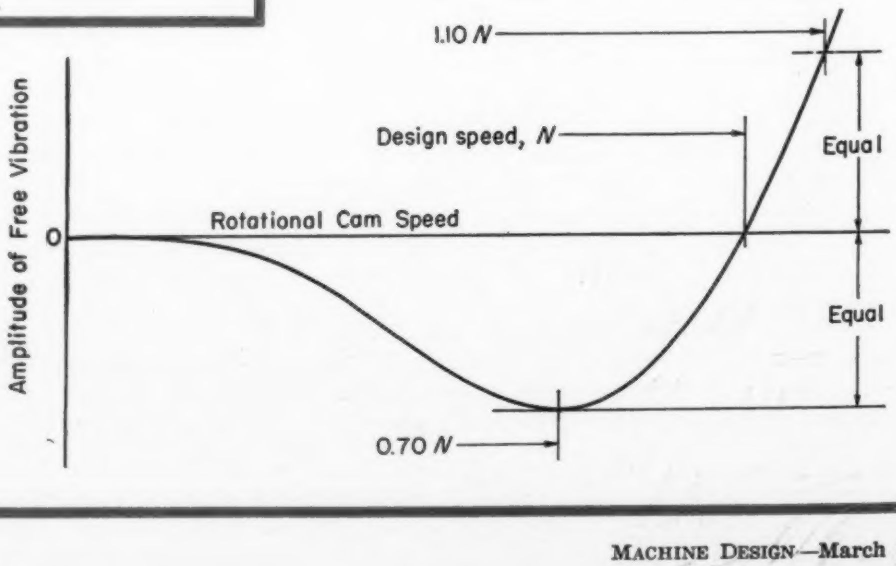


Fig. 3 — Characteristic relationship of vibration amplitude of end element with cam shaft speed for polydyne cam and follower systems



and y^{iv} are given by preceding equations.

As shown in *Fig.* 1, the difference between y_0'' at 400 rpm and y'' is not great. However, between y_0'' at 800 rpm and y'' the difference is so great as to be almost absurd.

In *Fig.* 1 the equivalent cam displacement for N = 800 rpm is plotted from the equation

$$y_0 = y_r + 1.04\, y + 64\, y''$$

where ramp height y_{rmax} = 0.07-inch, a value obtained by consideration of the "security" aspects of the design. That is, if y_0 had started at zero at $x/x_r = 1$ (75 deg), the y_0 curve would have fallen beneath the curve for y a maximum of 0.07-inch at about x/x_r = 0.30 (22½ deg from top of rise). Compression in the linkage over the full event requires a ramp of this height, or graphically, the entire y_0 curve must be raised 0.07-inch. The critical point of $x/x_r = 0.30$ is the point of greatest negative acceleration which is where the demand upon the return spring is the greatest. Any clearance in the system would be added to the 0.07-inch ramp height established by the dynamic loading.

Some indication of the relationship of return spring load to dynamic forces has already been given in reference to *Fig.* 7 of the second article. Further clarification is provided by *Fig.* 2 presented here. In *Fig.* 2, the outer or upper solid line is the equivalent cam lift. The lower solid line is the end element lift at a speed very low in relation to design speed. The difference in their ordinates is the static deflection induced by the return spring. Any departure from the lower line is caused by dynamic deflection. Such departure is shown by the dashed line which represents some speed significant in relation to design speed. At the point of greatest departure below the lower solid line, the end element is at maximum positive acceleration. Conversely, at the point of greatest departure above the line, the end element is at its maximum negative acceleration. If the end element lift goes above the upper line, tension rather than compression in the linkage would prevail—an impossibility with a spring-return system. Hence, security would be lost, and parts of the system would separate.

Vibration: This account of the transition of the actual end mass displacement curve between two limits as speed increases from zero to design speed is accurate enough—until vibration is considered. Between zero and design speed and above design speed, vibration can cause effects not depicted in *Figs.* 1 or 2.

The equation relating displacements of the end mass and the equivalent cam might be rewritten as

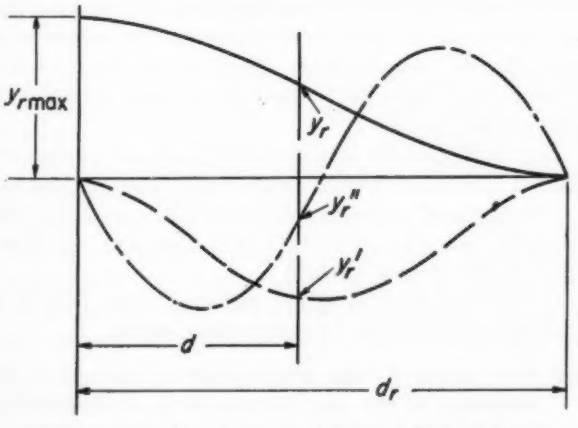
$$y_0 = y_r + \rho y + \frac{0.093\, w\, N^2}{k_0}\, y''$$

Letting $W = 0.093\, w/k_0$ and rearranging,

$$y = \frac{y_0 - y_r}{\rho} - \frac{WN^2}{\rho}\, y''$$

This expression can be handled as a differential equation with two solutions for y as N is varied. One set of solutions expresses the effect of the change in dynamic loading from change in acceleration; the second set expresses the amplitude of free vibration of the system at the designated speed. Calculations of the free vibrations for several polydyne cam systems

Fig. 4—Inflected type ramp and equations. Equations presented are for the 3-4-5 polynomial, but any other function possessing the same general characteristics might also be used

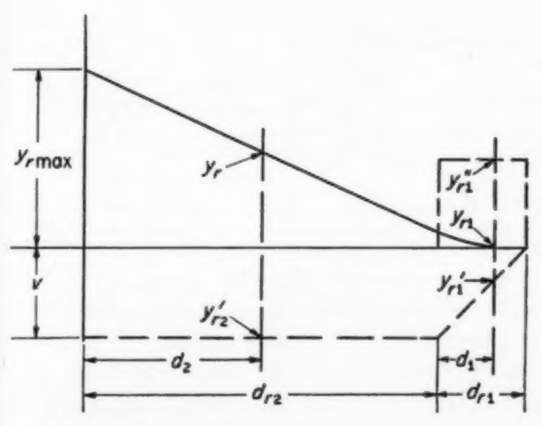


$$y_r = y_{r\,max}\left[1 - 10\left(\frac{d}{d_r}\right)^3 + 15\left(\frac{d}{d_r}\right)^4 - 6\left(\frac{d}{d_r}\right)^5\right]$$

$$y_r' = \frac{y_{r\,max}}{d_r}\left[-30\left(\frac{d}{d_r}\right)^2 + 60\left(\frac{d}{d_r}\right)^3 - 30\left(\frac{d}{d_r}\right)^4\right]$$

$$y_r'' = \frac{y_{r\,max}}{d_r^2}\left[-60\left(\frac{d}{d_r}\right) + 180\left(\frac{d}{d_r}\right)^2 - 120\left(\frac{d}{d_r}\right)^3\right]$$

Fig. 5 — Constant-velocity type ramp. First stage is shown as a constant-acceleration portion, but other functions could be employed to advance velocity from zero to the value required at the second stage



y_{r1}'' = S = Selected constant

$y_{r1}' = S = (d_1 - d_{r1})$

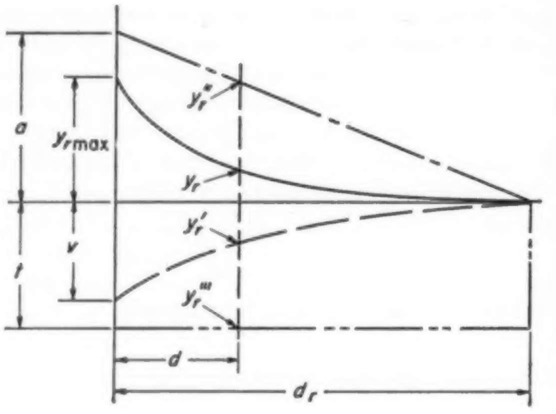
$y_{r1} = \frac{S}{2}(d_1 - d_{r1})^2$

$y_{r2}' = -S d_{r1}$

$y_r = -S d_{r1}(d_2 - d_{r2}) + \frac{S}{2} d_{r1}^2$

established the characteristic curve shown in *Fig.* 3. The ordinate values of this curve differ according to differing system properties but the characteristic shape prevails.

Calculations for other than design speed are tedious and time consuming. Therefore, vibration analysis is seldom practical. The curve of *Fig.* 3, however, can serve as a guide in design. For any particular system, the maximum amplitude (at 70 per cent design speed N) is proportional to the difference in shape and ordinates of the y_0'' and y'' curves. Thus, in *Fig.* 1, the system designed for 800 rpm would have far greater vibration amplitude between zero and design speed than would the system designed for 400 rpm.



$y_r''' = f =$ Selected constant

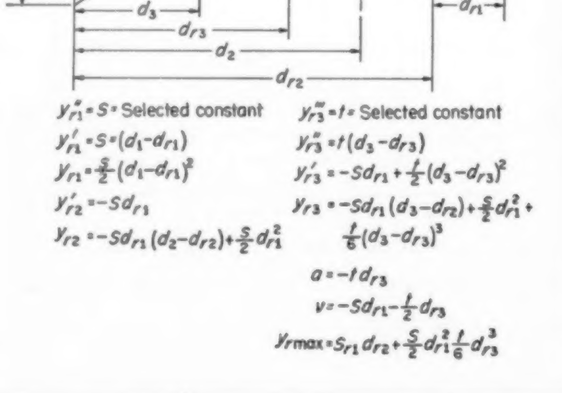
$y_r'' = f = (d - d_r)$

$y_r = \frac{f}{6}(d - d_r)^3$

$y_r' = \frac{f}{2}(d - d_r)^2$

Fig. 6—Constant-jerk ramp, also known as uniformly increased acceleration ramp

Fig. 7—Combination ramp consisting of three stages: (1) constant acceleration, (2) constant velocity, (3) constant jerk



$y_{r1}'' = S =$ Selected constant

$y_{r1}' = S = (d_1 - d_{r1})$

$y_{r1} = \frac{S}{2}(d_1 - d_{r1})^2$

$y_{r2}' = -Sd_{r1}$

$y_{r2} = -Sd_{r1}(d_2 - d_{r2}) + \frac{S}{2}d_{r1}^2$

$y_{r3}''' = f =$ Selected constant

$y_{r3}'' = f(d_3 - d_{r3})$

$y_{r3}' = -Sd_{r1} + \frac{f}{2}(d_3 - d_{r3})^2$

$y_{r3} = -Sd_{r1}(d_3 - d_{r2}) + \frac{S}{2}d_{r1}^2 + \frac{f}{6}(d_3 - d_{r3})^3$

$a = -fd_{r3}$

$v = -Sd_{r1} - \frac{f}{2}d_{r3}$

$y_{r\,max} = S_{r1}d_{r2} + \frac{S}{2}d_{r1}^2 \frac{f}{6}d_{r3}^3$

Vibrational amplitudes may be additive to the end element lift at any point. They can be great enough to cause y to exceed y_0 at a given point. Then compression in the linkage becomes zero and the parts separate. Occasionally a polydyne cam has lost control from this cause in the range of 0.70 N and then regained control for a range through design speed. These observations bear out the validity of the mathematical concept.

If the speed range of lost control is short and the degree of loss is not severe, correction can usually be obtained by an increase in the initial load of the return spring, an increase in its rate, or both. However, increasing spring load without redesigning the cam incurs certain penalties:

1. Total lift of the end element is reduced.
2. Events are shortened as design requirements at opening and closing are displaced.
3. Above design speed, when control is lost, system forces become more severe.

Ramp Design: To complete the design of *Fig.* 1, the details must be worked out for the ramp or subcam required to raise the follower 0.07-inch before the end element starts to move. Initial specifications for the design set lift and its first four derivatives at zero at the 75-deg position ($x/x_r = 1$), which is also the terminus of the ramp. Therefore, an inflected ramp of the type shown in *Fig.* 4 must be used.

The form of this ramp is the same as a dwell-rise-dwell cam. The height is dictated, of course, by the requirements of the main event, but the range of cam rotation occupied by the ramp is arbitrary or is governed by other design considerations.

Different types of ramps, however, are dictated by various design conditions. In fact, ramp requirements may substantially influence the design of the main cam.

Besides the inflected type ramp shown in *Fig.* 4, two other forms in use are: constant-velocity type, *Fig.* 5, and uniformly increased acceleration or constant-jerk type, *Fig.* 6. Additionally, these latter two forms can be combined into the constant-velocity constant-jerk type shown in *Fig.* 7.

The utility of these different types with automotive cams (dwell-rise-return-dwell type) can be discussed on the basis of considerable experience, and the points brought out may aid their adoption or rejection in other fields of cam design.

Several drawbacks of the inflected type, *Fig.* 4, prevent its common use in automotive work.

1. The relatively flat termination of the ramp and initiation of the cam coupled with flexibility, tolerance, and clearance variations between linkages lead to a wide range of actual event locations.
2. For valve closing, the approach of the valve to the seat is so slow that valve burning is encouraged. "Easing in" of the valve fails to promote crushing of foreign particles on the seat and valve face.
3. If the system has clearance, the point of pick up (clearance taken up) may be at a relatively high

velocity or acceleration, and noise or vibration may result.

When acceleration is zero at the terminus of the ramp and the start of the cam, the constant velocity type, *Fig.* 5, is frequently used for several reasons:

1. The same contact velocity occurs in each linkage, regardless of differences in clearances and flexibility on both the rise and return sides.
2. By comparison with the inflected type, variation in event location is less.
3. It is the simplest to design, and may be increased or decreased in height without affecting the main cam profile.

A constant-jerk ramp, *Fig.* 6, can be used only when a finite acceleration is permitted at the initiation of the main cam event. Also, it is limited to linkage systems that have no clearances. Moreover, in automotive design they are restricted to the opening side, because on the closing side the valve must be seated at a low velocity near the top of the ramp. Its advantages on the opening side are:

1. The location of the event is pinpointed.
2. The valve can be opened faster with a lower maximum acceleration because part of the dynamic load has been transmitted to the linkage system before the valve opens.

Compared in *Fig.* 8 are calculated lift and acceleration curves for the end element when the equivalent cam starts with

1. Zero velocity and acceleration (curves ${}_ny$ and ${}_ny''$).
2. A finite ramp velocity and zero acceleration (curves ${}_vy$ and ${}_vy''$).
3. Same velocity as preceding case and a finite acceleration (curves ${}_{va}y$ and ${}_{va}y''$).

As each further condition is added, the following advantages accumulate:

1. Maximum acceleration is reduced.
2. Area under the lift curve is increased.
3. Negative acceleration (and thus return spring demand) is reduced.
4. Inflection point is closer to the initiation of the rise.
5. The point of maximum acceleration is nearer the initiation of the rise.

When a constant-jerk ramp is applied, the velocity permissible is usually two to three times as great as that used in the example of *Fig.* 8. Ordinarily, therefore, the differences shown and the advantages noted would be considerably greater.

For the same conditions outlined in reference to *Fig.* 8, the displacement and acceleration curves for the equivalent cam are plotted in *Fig.* 9. Here detailed differences are more noticeable, but again a higher velocity with the uniformly accelerated or constant jerk ramp would have shown more striking differences.

The combination type ramp, *Fig.* 7, consisting of an initial constant-velocity portion and a continuing constant-jerk region, offers considerable flexibility in design. It can be used in systems having clearance. In effect, the clearance is taken up over the constant velocity portion and the static spring forces are overcome during the concluding acceleration stage of the ramp.

Working Equations: Because of some of the foregoing considerations, equations for actual calculations might be so set up as to anticipate and embrace differences between the equivalent cam and end element characteristics. At the initiation of the event, the end element has zero lift, velocity and acceleration, but the equivalent cam may have specified finite values at this same point, such as: lift (ramp height) $y_{r\,max}$, velocity v, and acceleration a. Then, at $x = 1$ in the "unit" system,

$$y_0 = y_r + \rho y + \phi y'' = y_{r\,max}, \quad y = 0, \quad y'' = 0$$

$$y_0' = \rho y' + \phi y''' = v, \quad y' = 0, \quad y''' = \frac{v}{\phi}$$

$$y_0'' = \rho y'' + \phi y^{iv} = a, \quad y'' = 0, \quad y^{iv} = \frac{a}{\phi}$$

These relationships can be built into equations for the coefficients of the end element polynomial by consideration of the physical dimensions of the event range, lift, velocity, etc. Such working equations for the coefficients are presented here in TABLE 1.

Automotive Example: The methods employed in a complete calculation are best depicted in detail for an automotive cam and follower system—the field in which polydyne cam design was developed.

From tests and observations of the sort described in

Table 1—Coefficients of Working Equations

Equation:

$$y = y_{max} + C_p\left(\frac{x}{x_r}\right)^p + C_q\left(\frac{x}{x_r}\right)^q + C_r\left(\frac{x}{x_r}\right)^r + C_s\left(\frac{x}{x_r}\right)^s + C_t\left(\frac{x}{x_r}\right)^t$$

where y = displacement of end element, inches; y_{max} = maximum lift, inches; x = cam position, deg; x_r = event range, deg; x/x_r = decimal portion of event range.

Coefficients:

$$C_p = \frac{-\,qrst\,y_{max} - (q+r+s+t-6)\,V + A}{(q-p)(r-p)(s-p)(t-p)}$$

$$C_q = \frac{-\,prst\,y_{max} - (p+r+s+t-6)\,V + A}{(p-q)(r-q)(s-q)(t-q)}$$

$$C_r = \frac{-\,pqst\,y_{max} - (p+q+s+t-6)\,V + A}{(p-r)(q-r)(s-r)(t-r)}$$

$$C_s = \frac{-\,pqrt\,y_{max} - (p+q+r+t-6)\,V + A}{(p-s)(q-s)(r-s)(t-s)}$$

$$C_t = \frac{-\,pqrs\,y_{max} - (p+q+r+s-6)\,V + A}{(p-t)(q-t)(r-t)(s-t)}$$

where $V = x_r^3 v/\phi$; $A = x_r^4\,a/\phi$; v = velocity at x/x_r = 1, in. per deg; a = acceleration at x/x_r = 1, in. per deg^2.

the second article of this series, certain of the following data were obtained for a particular valve system and the remaining data were set as design requirements:

1. Effective weight at the end element (the valve, etc.) $w = 0.516$-lb.
2. Static equivalent cam opening ramp height $_{o}y_{r\,max} = 0.0085$-inch.
3. Static equivalent cam closing ramp height $_{c}y_{r\,max} = 0.0086$-inch.
4. Follower system spring rate $k_0 = 20{,}000$ lb per in.
5. Return spring rate $k_1 = 300$ lb per in.
6. System shall have zero-clearance adjusters.
7. Design speed of engine shall be 5000 rpm; cam shaft design speed N is one-half engine speed, or $N = 2500$ rpm.
8. Total of opening and closing events shall be 123 deg; on opening side event range $_{o}x_r = 60$ deg; on closing side event range $_{c}x_r = 63$ deg.
9. Maximum valve lift at design speed $y_{max} = 0.350$-inch.
10. Rocker arm ratio $R_l = 1.5$.

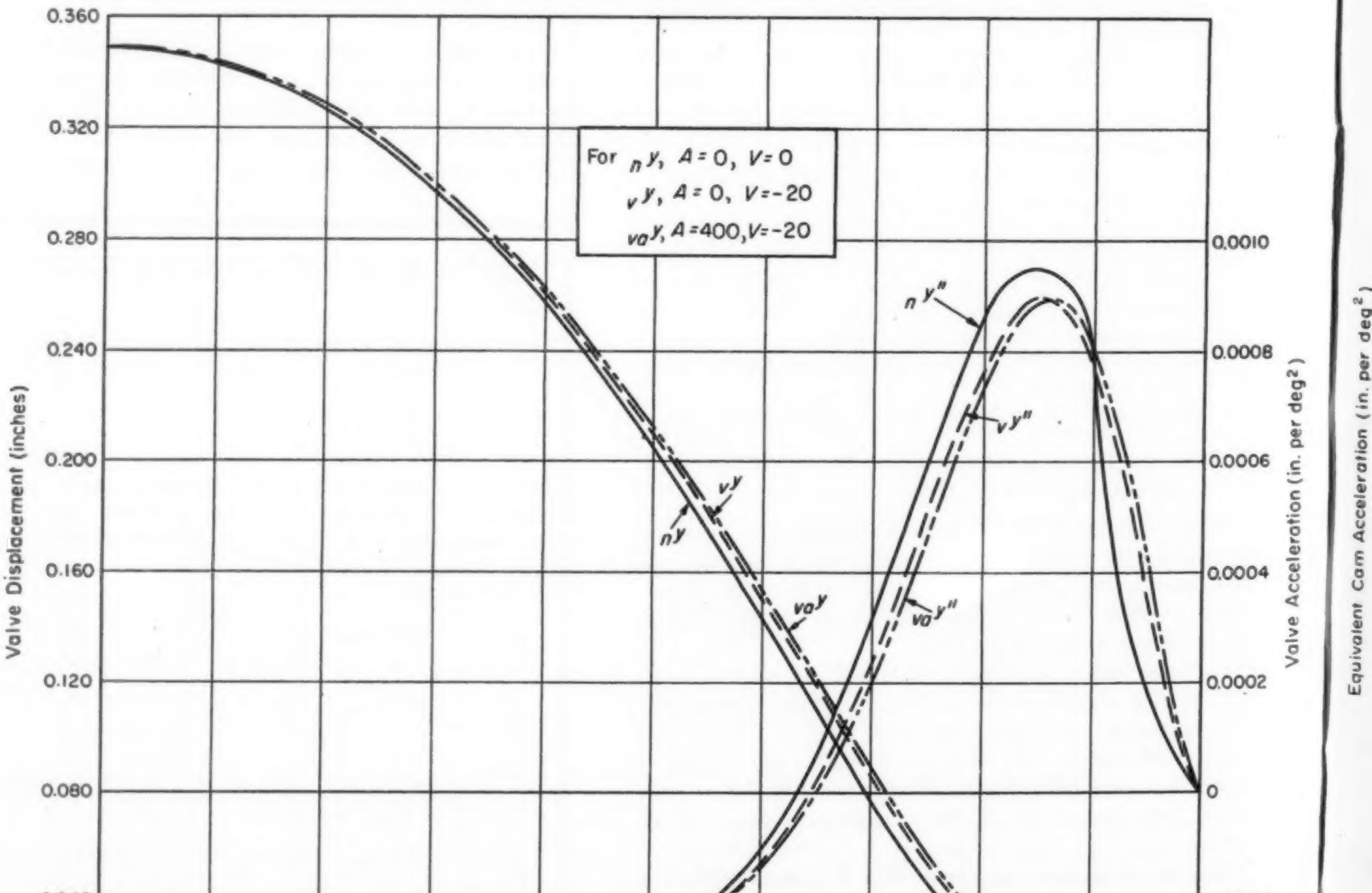
From the above data, ρ and ϕ can be immediately evaluated:

$$\rho = \frac{k_1 + k_0}{k_0} = \frac{20{,}000 + 300}{20{,}000} = 1.015$$

$$\phi = \frac{0.093\, w\, N^2}{k_0} = \frac{0.093(0.516)(2500)^2}{20{,}000} = 15.00$$

With no clearance to be taken up by the ramp, a constant-jerk ramp, ***Fig.*** 6, can be used to open the valve. This ramp will have to be higher than the 0.0085-inch static requirement due to the dynamic deflection created in the linkage before the valve leaves its seat. According to theory, the dynamic deflection of the system is proportional to the acceleration of the valve, but the equation for the equivalent cam lift holds only when the valve is in motion. Actually the static ramp height chosen was numerically the largest

Fig. 8—Valve displacement and acceleration curves for a 2-10-22-24 polynomial. Spring factor $\rho = 1.01$ and dynamic factor $\phi = 10$. The three pairs of curves represent the effect of three sets of ramp conditions on the end element at design speed. Inset tabulation gives the ramp data used in the calculations



of all the linkages tested. But other engines of the same model may have even larger static ramp requirements. The other linkages with lower requirements will start lifting the valve from the seat before the top of the ramp is reached. Therefore, the additional height of ramp for system dynamic deflection can only be approximated.

If the ramp, at its junction with the cam, shall be assumed to provide an acceleration of 0.0003 in. per deg^2, and the effective mass-acceleration of the system equivalent weight were assumed to be about one-half, or 0.0015 in. per deg^2, the dynamic deflection in the system at the top of the ramp would be $y_d = \phi a/2 = 15(0.00015) = 0.00225$. Then the maximum ramp height must approximately equal the static deflection plus the estimated dynamic deflection, or $y_{rmax} = 0.0085 + 0.00225 = 0.01075$.

With an attempt made to maintain a at about 0.0003 and v at about 0.0025, trial and error show that a jerk value of $t = -0.000024$ in. per deg^3 and a ramp range $d_r = 14$ deg satisfy the requirements within practical limits. Or, from *Fig.* 6,

$$y_{r\,max} = \frac{-0.000024}{6}(-14)^3 = 0.010976 \text{ inch}$$

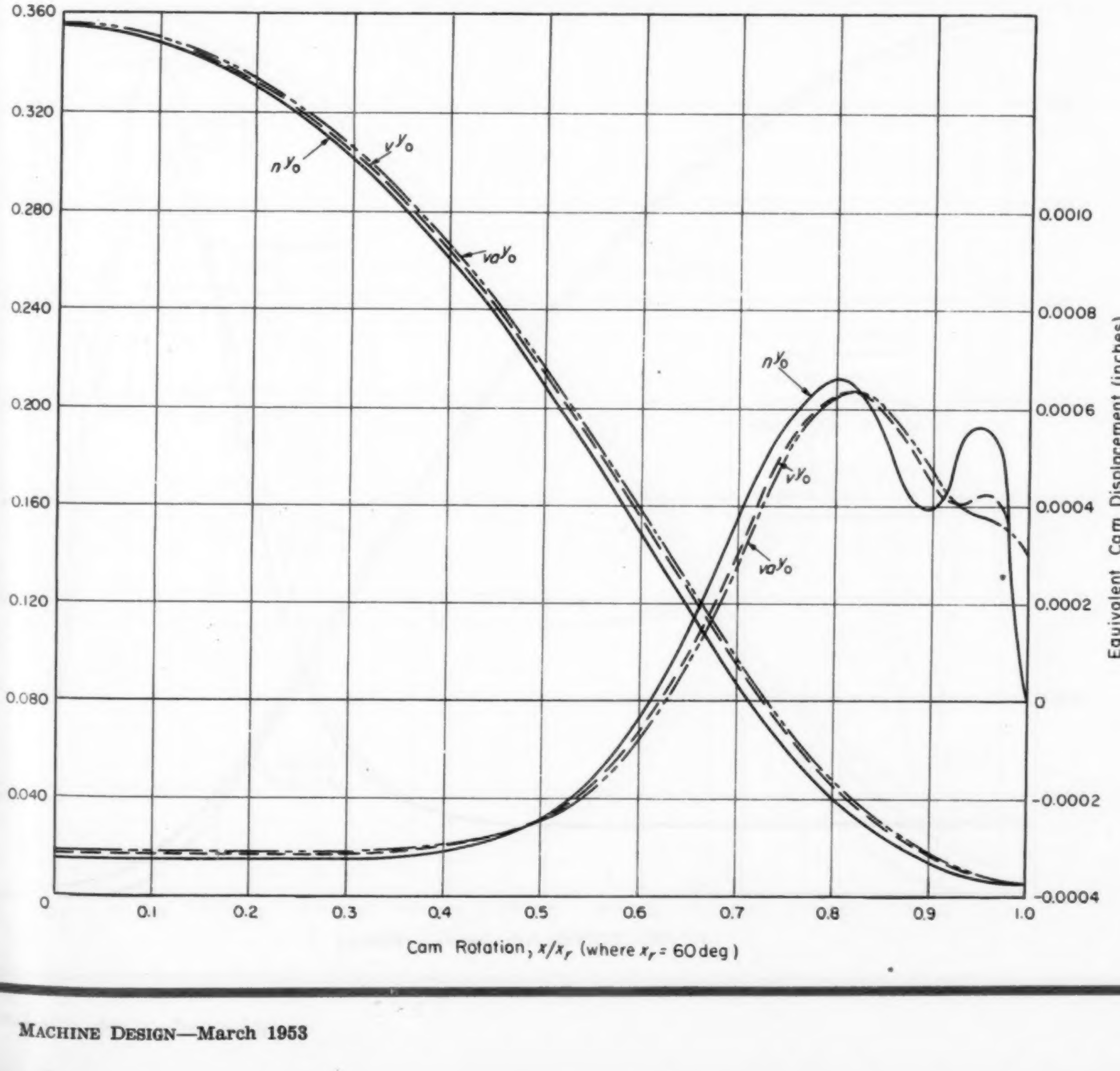
$$v = \frac{-0.000024}{2}(-14)^2 = -0.002352 \text{ in. per deg}$$

$$a = -0.000024\,(-14) = 0.000336 \text{ in. per deg}^2$$

Values for displacement and velocity at intermediate points can be readily computed from the equations presented in *Fig.* 6.

Junction values just computed are next used in the calculation of factors V and A (see TABLE 1) needed in the determination of the "working" coefficients.

Fig. 9—Equivalent cam displacement and acceleration curves corresponding to the valve curves shown in *Fig.* 8



Valve Acceleration (in. per deg^2)

As identified at the foot of TABLE 1,

$$V = \frac{v_o x_r^3}{\phi} = \frac{-0.002352(60)^3}{15} = -33.8688$$

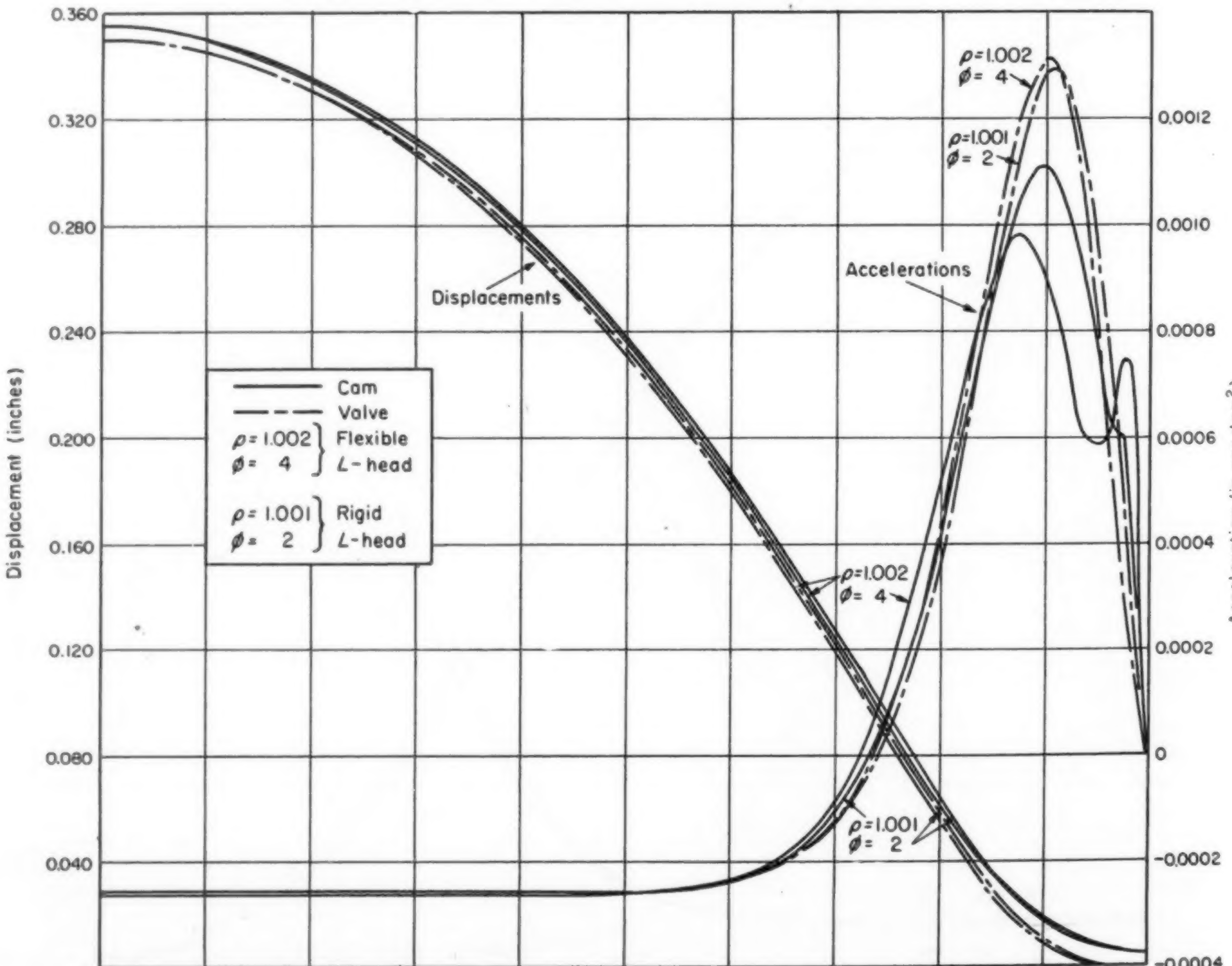
$$A = \frac{a_o x_r^4}{\phi} = \frac{0.000336(60)^4}{15} = 290.304$$

The next step is to choose those powers of x that will give the desired lift with the maximum area under the lift curve consistent with favorable dynamics. Several examples may serve as preliminary guides in this operation. *Fig.* 10 shows lift, velocity and acceleration diagrams for equivalent cam and valve for two very rigid systems. These are typical of L-head engines. The powers used are 2-16-28-36-40. For this power series, the cam with $\phi = 2$ has valve and equivalent cam accelerations which approach each other in size and shape. The $\phi = 4$ equivalent cam acceleration shows a reversal of direction in the positive area, but the valley in depth is only 0.00016 in. per deg². The second apex is 0.00024 in. per deg² higher than the first. Both of these cams would perform satisfactorily.

In *Fig.* 11, the same power series, lift and range are employed on three cams that are in the over-head valve engine class. The absurdity of this power series for valves of ϕ above 10 is quite evident. When $\phi = 15$ and $\rho = 1.015$, as in the example under consideration, the equivalent cam maximum acceleration is nearly twice the maximum valve acceleration and occurs after only 2 per cent of the lift has been completed as compared to 10 per cent of the lift for the valve. Successful cams have been designed in which the acceleration drops to negative and returns to positive, but never beyond that shown for $\phi = 10$. For best results the following rules are suggested to govern equivalent cam acceleration curves:

1. The first apex should not be more than about 15

Fig. 10—Valve and equivalent cam curves for a 2-16-28-36-40 polynomial preceded by a constant-velocity ramp (0.0005-in. per deg). These designs are typical of L-head systems



per cent greater than the second.

2. The maximum equivalent cam acceleration y_0'' should always be less than the maximum valve acceleration y''.
3. The positive equivalent cam acceleration should not become negative and then reenter the positive area.
4. When the rate of change and irregularity of the acceleration curve are held to a minimum, cams will produce more satisfactory results at the in-between speeds.

These rules are not hard and fast, and may well be modified by experience in different ranges of the variables involved.

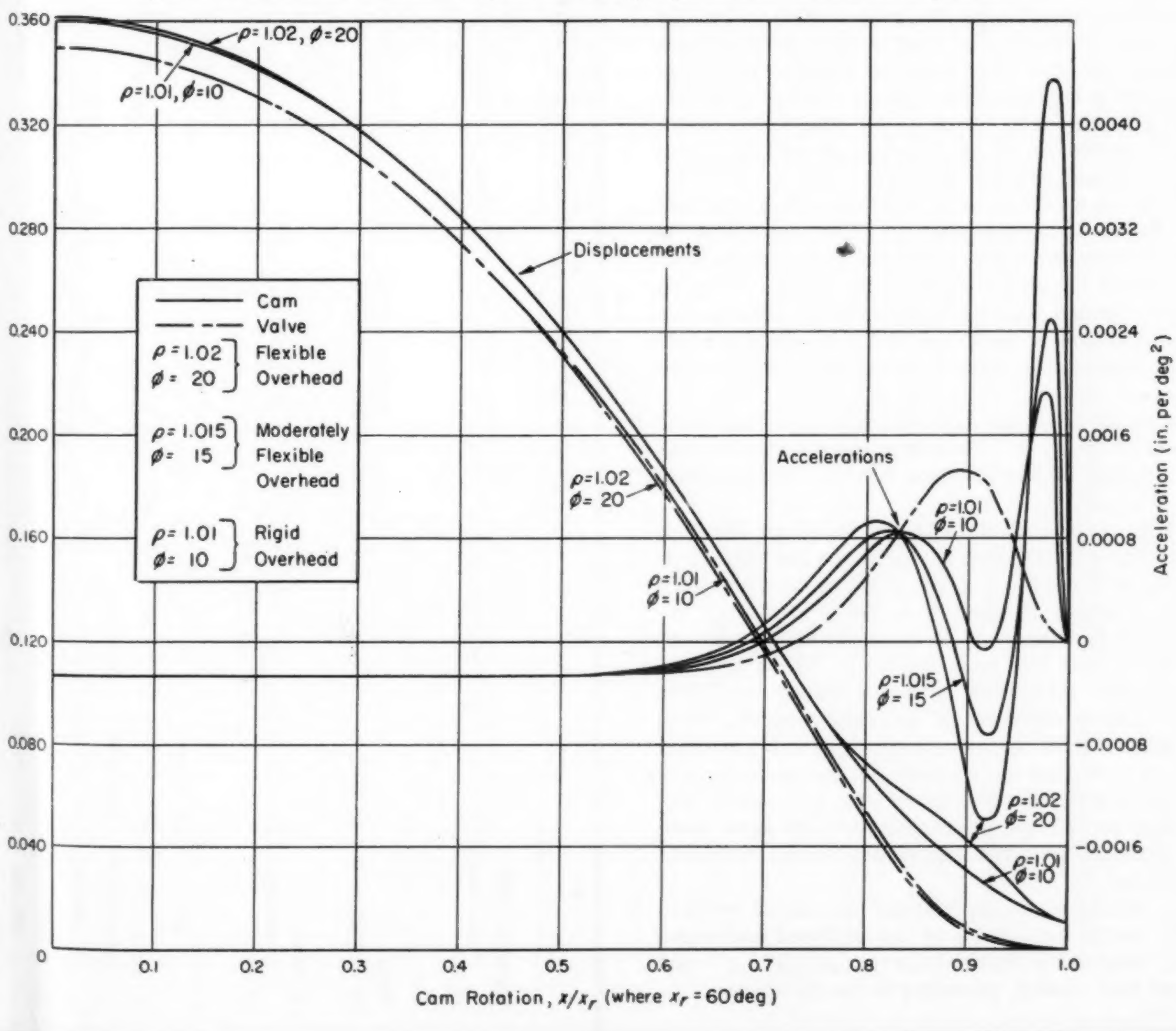
From *Fig.* 11 it is evident that powers 2-16-28-36-40 are too high for $\rho = 1.015$ and $\phi = 15$. A more satisfactory power series would be 2-10-20-30-40. The amount of change effected by each alteration in a power, incidentally, is proportional to the percentage change in that power, instead of to the numerical difference alone. That is, a change from 12 to 16, for example, is more significant than one from 20 to 24—an increase of 33 per cent versus 20 per cent.

These powers are then used in the calculation of the coefficients according to the equations given in TABLE 1. The actual process is shown on Work Sheet 1. Solutions for the coefficients can be checked in part or as a whole. The algebraic sum of the A portions and the V portions must equal zero. The algebraic sum of the y_{max} portions must equal $-y_{max}$.

Next the equations for y and its four derivatives are formed from these coefficients as shown in Work Sheet 2.

The derivatives are established and checked in progression except for the third derivative. It is derived directly from the initial equation to show the method of establishing any derivative directly. In practice, if all four derivatives are desired, carrying each power

Fig. 11—Curves built on same conditions as those in *Fig.* 10, except for spring and dynamic factors which have been given values appropriate in overhead-valve systems



through the successive derivatives individually saves time and insures accuracy. With respect to a check of the results obtained by algebraic addition, factors concerning the third and fourth derivatives might be clarified by a brief review. The coefficients were determined from five simultaneous equations describing lift and its first four derivatives at the point where $x/x_r = 1$. For convenience in calculations and their use, each successive derivative was multiplied by the range x_r so that $y = 0$, $x_r y' = 0$, $x_r^2 y'' = 0$, $x_r^3 y'' = x_r^3 v/\phi = V$ and $x_r^4 y^{iv} = x_r^4 a/\phi = A$. Thus the values of y'' and y^{iv} will be V/x_r^3 and A/x_r^4.

Now that the equations for lift and its four derivatives have been established for the opening side, the principal remaining operations are to calculate curve points for the valve and the equivalent cam. Demonstration of all typical calculations required in this work is provided by Work Sheets 3 to 6, and results are plotted in ***Fig.* 12**.

The work sheet method for point calculations is simple and straight forward. The values for $x/_o x_r$ shown in the left-hand column of Work Sheet 3 are raised to the power indicated by the exponent in the heading of each column. These may be read directly from the powers given in TABLE 2 in the first article. The corresponding coefficient is then multiplied and the answer tabulated in its proper position in the table. The values of $x/_o x_r$, used in the work sheet may be chosen to give the greatest number of points throughout a critical range. Those chosen in the example give the best coverage for automotive work without calculation of extra points where the curves are smooth and uniform in nature.

The use of a calculator is required to keep the task from becoming overwhelming. The coefficient is locked into the keyboard of the machine and the complete column is calculated before its release. If work proceeds upward from the bottom of the column, the decimal location is easily found for the first product and its location maintained for the remainder of the column.

The values of $_oy$ are then determined by algebraic addition of each row. Thus each row becomes a complete solution of the equation for the corresponding value of $x/_o x_r$.

In the sample calculations for $_oy$, Work Sheet 4, much of the notation that is repetitious has been omitted. Work Sheet 5 for $_oy''$ does not contain a column for the constant. Instead, it is placed in the $_oy''$ column in the row for $x/_o x_r = 0$. It enters into the calculation of each row as it did for $_oy$. With practice, the complete calculation need not require any more entries than is shown for $_oy''$ for each equation. Note that $_oy''$ is carried one more decimal place beyond that of $_oy$; it will then be accurate to the same decimal place as $_oy$ when it is multiplied by ϕ ($\phi = 15$). The equations for y''' and y^{iv} are solved in the same manner, although no work sheets are shown for these calculations.

The values for $_oy_o$, $_oy_o'$ and $_oy_o''$ are solved by locking the values for ρ and ϕ in the keyboard and multiplying the results obtained for $_oy$, $_oy'$, $_oy''$, $_oy'''$ and $_oy^{iv}$ and then adding, according to the equations:

$$y_o = y_r + \rho y + \phi y''$$

Work Sheet 1—Coefficients for Opening Side

Equation form:

$$C_p = \frac{A - (q + r + s + t - 6)V - qrsty_{max}}{(q-p)(r-p)(s-p)(t-p)}$$

Data:

$A = 290.304$, $V = 33.8688$, $y_{max} = 0.350$, $p = 2$, $q = 10$, $r = 20$, $s = 30$, $t = 40$

Solution:

$$C_2 = \frac{290.304 - (10 + 20 + 30 + 40 - 6)(-33.8688) - 10(20)(30)(40)(0.350)}{(10-2)(20-2)(30-2)(40-2)}$$

$$= \frac{290.304 + 94(33.8688)}{8(18)(28)(38)} - \frac{10(20)(30)(40)(0.350)}{8(18)(28)(38)}$$

$$= 0.0226737 - 0.5482456 = -0.5255719$$

$$C_{10} = \frac{290.304 - (2 + 20 + 30 + 40 - 6)(-33.8688) - 2(20)(30)(40)(0.350)}{(2-10)(20-10)(30-10)(40-10)}$$

$$= \frac{290.304 - 86(33.8688)}{-8(10)(20)(30)} + 0.350$$

$$= -0.0667296 + 0.350 = 0.2832704$$

$$C_{20} = \frac{290.304 - (2 + 10 + 30 + 40 - 6)(-33.8688) - 2(10)(30)(40)(0.350)}{(2-20)(10-20)(30-20)(40-20)}$$

$$= 0.0795648 - 0.2333333 = -0.1537685$$

$$C_{30} = \frac{290.304 - (2 + 10 + 20 + 40 - 6)(-33.8688) - 2(10)(20)(40)(0.350)}{(2-30)(10-30)(20-30)(40-30)}$$

$$= 0.0451008 + 0.1000000 = 0.0548992$$

$$C_{40} = \frac{290.304 - (2 + 10 + 20 + 30 - 6)(-33.8688) - 2(10)(20)(30)(0.350)}{(2-40)(10-40)(20-40)(30-40)}$$

$$= 0.0095919 - 0.0184210 = -0.0088291$$

Check:

$$0.0226737 - 0.0667296 + 0.0795648 - 0.0451008 + 0.0095919 = 0$$

$$-0.5482456 + 0.350 - 0.2333333 + 0.100 - 0.0184210 = -0.350000$$

$$-0.5255719 + 0.2832704 - 0.1537685 + 0.0548992 - 0.0088291 = -0.350000$$

$$= \frac{290.304 - 86(33.8688)}{-8(10)(20)(30)} + 0.350$$

$$-0.5255719 + 0.2832704 - 0.1537685 + 0.0548992 - 0.0088291 = -0.350000$$

Work Sheet 2—Derivative Equations

Displacement equation:

$$y = 0.350 - 0.5255719\left(\frac{x}{60}\right)^{2} + 0.2832704\left(\frac{x}{60}\right)^{10} - 0.1537685\left(\frac{x}{60}\right)^{20} +$$

$$0.0548992\left(\frac{x}{60}\right)^{30} - 0.0088291\left(\frac{x}{60}\right)^{40}$$

Derivatives:

$$y' = -\frac{2(0.5255719)}{60}\left(\frac{x}{60}\right) + \frac{10(0.2832704)}{60}\left(\frac{x}{60}\right)^{9} -$$

$$\frac{20(0.1537685)}{60}\left(\frac{x}{60}\right)^{19} + \frac{30(0.0548992)}{60}\left(\frac{x}{60}\right)^{29} -$$

$$\frac{40(0.0088291)}{60}\left(\frac{x}{60}\right)^{39}$$

$$= -0.0175191\left(\frac{x}{60}\right) + 0.0472117\left(\frac{x}{60}\right)^{9} - 0.0512562\left(\frac{x}{60}\right)^{19} +$$

$$0.0274496\left(\frac{x}{60}\right)^{29} - 0.0058861\left(\frac{x}{60}\right)^{39}$$

y' check:

$$-0.0175191 + 0.0472117 - 0.0512562 + 0.0274496 - 0.0058861 = 0$$

$$y'' = -\frac{0.0175191}{60} + \frac{9(0.0472117)}{60}\left(\frac{x}{60}\right)^{8} - \frac{19(0.0512562)}{60}\left(\frac{x}{60}\right)^{18} +$$

$$\frac{29(0.0274496)}{60}\left(\frac{x}{60}\right)^{28} - \frac{39(0.0058861)}{60}\left(\frac{x}{60}\right)^{38}$$

$$= -0.0002920 + 0.0070817\left(\frac{x}{60}\right)^{8} - 0.0162311\left(\frac{x}{60}\right)^{18} +$$

$$0.0132673\left(\frac{x}{60}\right)^{28} - 0.0038259\left(\frac{x}{60}\right)^{38}$$

y'' check:

$$-0.0002920 + 0.0070817 - 0.0162311 + 0.0132673 - 0.0038259 = 0$$

$$y''' = \frac{10(9)(8)(0.2832704)}{(60)^3}\left(\frac{x}{60}\right)^{7} - \frac{20(19)(18)(0.1537685)}{(60)^3}\left(\frac{x}{60}\right)^{17} +$$

$$\frac{30(29)(28)(0.0548992)}{(60)^3}\left(\frac{x}{60}\right)^{27} - \frac{40(39)(38)(0.0088291)}{(60)^3}\left(\frac{x}{60}\right)^{37}$$

$$= 0.0009442\left(\frac{x}{60}\right)^{7} - 0.0048693\left(\frac{x}{60}\right)^{17} + 0.0061914\left(\frac{x}{60}\right)^{27} -$$

$$0.0024231\left(\frac{x}{60}\right)^{37}$$

y''' check:

$$0.0009442 - 0.0048693 + 0.0061914 - 0.0024231 = -0.0001568$$

$$v = \frac{V}{x_r^{3}} = \frac{-33.8688}{(60)^3} = -0.0001568$$

$$y^{iv} = \frac{0.0009442}{60}\left(\frac{x}{60}\right)^{6} - \frac{0.0048693}{60}\left(\frac{x}{60}\right)^{16} + \frac{0.0061914}{60}\left(\frac{x}{60}\right)^{26} -$$

$$\frac{0.0024231}{60}\left(\frac{x}{60}\right)^{36}$$

$$= 0.0001102\left(\frac{x}{60}\right)^{6} - 0.0013796\left(\frac{x}{60}\right)^{16} + 0.0027861\left(\frac{x}{60}\right)^{26} -$$

$$0.0014942\left(\frac{x}{60}\right)^{36}$$

y^{iv} check:

$$0.0001102 - 0.0013796 + 0.0027861 - 0.0014942 = 0.0000225$$

$$a = \frac{A}{x_r^{4}} = \frac{290.304}{(60)^4} = 0.0000225$$

Work Sheet 3—Valve Displacement

$\frac{x}{x_r}$	x	y	0.350	$-\ 0.525572\left(\frac{x}{x_r}\right)^2$	$+\ 0.283270\left(\frac{x}{x_r}\right)^{10}$	$-\ 0.153769\left(\frac{x}{x_r}\right)^{20}$	$+\ 0.054899\left(\frac{x}{x_r}\right)^{30}$	$-\ 0.008829\left(\frac{x}{x_r}\right)^{40}$
0	0	0.350	0.350	−0	+0	−0	+0	−0
0.10	6.0	0.344744	0.350	−0.005256	....	....	....	....
0.20	12.0	0.328977	0.350	−0.021023	....	....	....	....
0.30	18.0	0.302700	0.350	−0.047302	+0.000002	....	....	....
0.40	24.0	0.265938	0.350	−0.084092	+0.000030	....	....	....
0.50	30.0	0.218884	0.350	−0.131393	+0.000277	....	....	....
0.60	36.0	0.162501	0.350	−0.189206	+0.001713	−0.000006	....	....
0.70	42.0	0.100350	0.350	−0.257530	+0.008002	−0.000123	+0.000001	....
0.75	45.0	0.069840	0.350	−0.295634	+0.015952	−0.000488	+0.000010	....
0.80	48.0	0.042344	0.350	−0.336366	+0.030416	−0.001773	+0.000068	−0.000001
0.82	49.2	0.032745	0.350	−0.353395	+0.038935	−0.002905	+0.000143	−0.000003
0.84	50.4	0.024282	0.350	−0.370344	+0.049544	−0.004704	+0.000294	−0.000008
0.86	51.6	0.017018	0.350	−0.388713	+0.062688	−0.007531	+0.000595	−0.000021
0.88	52.8	0.011094	0.350	−0.407003	+0.078891	−0.011927	+0.001186	−0.000053
0.90	54.0	0.006559	0.350	−0.425713	+0.098770	−0.018695	+0.002327	−0.000130
0.92	52.2	0.003376	0.350	−0.444844	+0.123049	−0.029015	+0.004450	−0.000314
0.94	56.4	0.001404	0.350	−0.464395	+0.152574	−0.044609	+0.008578	−0.000743
0.96	57.6	0.000402	0.350	−0.484367	+0.188327	−0.067966	+0.016133	−0.001725
0.98	58.8	0.000048	0.350	−0.504759	+0.231453	−0.102657	+0.029947	−0.003935
1.00	60.0	0	0.350	−0.525572	+0.283270	−0.153769	+0.054899	−0.008829

Work Sheet 4—Valve Velocity

$\frac{x}{x_r}$	y'	$-\ 0.0175191\frac{x}{x_r}$	$+\ 0.0472117\left(\frac{x}{x_r}\right)^9$	$-\ 0.0512562\left(\frac{x}{x_r}\right)^{19}$	$+\ 0.0274496\left(\frac{x}{x_r}\right)^{29}$	$-\ 0.0058861\left(\frac{x}{x_r}\right)^{39}$
0	0	0				
0.10	−0.0017519	−0.0017519				
0.20	35038	35038	....			
0.30	52548	52557	+0.0000009			
0.40	69952	70076	124	....		
0.50	86675	87596	922	−0.0000001		
0.60	100388	105115	4758	31	....	
0.70	104157	122634	19052	584	+0.0000009	....
0.75	98047	131393	35449	2167	65	−0.0000001
0.80	83759	140153	63366	7387	425	10
0.82	75487	143657	79136	11809	869	26
0.84	65842	147160	98302	18666	1748	66
0.86	55069	150664	121489	29189	3459	164
0.88	43594	154168	149415	45177	6738	402
0.90	32042	157672	182908	69240	12929	967
0.92	21210	161176	222915	105127	24456	2278
0.94	11989	164680	270521	158189	45629	5270
0.96	5174	168183	326957	235993	84024	11979
0.98	−0.0001215	171687	393627	349174	152789	26770
1.00	0	−0.0175191	+0.0472117	−0.0512562	+0.0274496	−0.0058861

$$y_0' = \rho y' + \phi y'''$$

$$y_0'' = \rho y'' + \phi y^{iv}$$

Calculations for ${}_o y_0$ and ${}_o y_0''$ only are shown on Work Sheet 6.

For the actual cam lift data—the figures used in the manufacture of the cam—${}_o y_0$ must be divided by the rocker arm ratio R_l. Or, actual cam lift

$$z_0 = \frac{y_0}{R_l}$$

Radius of curvature of the cam is another factor possessing practical significance. It is useful in the calculation of surface compressive stress and also bears upon the practicality of the design with respect to the method to be employed in the manufacture of the cam. For a flat-face follower,

$$R_c = R_b + z_0 + 3283\, z_0''$$

where R_c = radius of curvature, inches; R_b = base radius of cam, inches; z_0 = actual cam lift, inches; and z_0'' = actual cam acceleration, in. per deg^2, = y_0''/R_l. The factor 3283 is deg^2 per radian.

Eccentricity, which governs the diameter of the follower, is given by the relationship

$$e = 57.3\, z_0'$$

where e = eccentricity in inches; z_0' = actual cam velocity, in. per deg, = y_0/R_l; and 57.3 is the factor for deg per rad.

Points for all essential qualities of the opening side have now been calculated and are shown plotted as curves in *Fig.* 12.

The closing side of an automotive cam requires a ramp which allows the valve to seat with sufficient energy to break away deposits but with little noise. A compromise velocity of 0.0005 in. per deg is usually accepted. A constant velocity must be used so that all valves will seat over a slightly variable range at the same noise level. The shortening of the valve gear before the valve is opened by the accelerated ramp will not exist on the closing side. As a result, the closing side lift ${}_c y_{max}$ will be greater than the opening side ${}_o y_{max}$ by the amount allowed for dynamic deflection on the ramp. On the other hand, from the hysteresis loop, static deflection on the closing side exceeded that on the opening side by 0.0001 inch. Therefore, ${}_c y_{max}$ is greater by $0.0025 - 0.0001 = 0.0024$ inch. Then ${}_c y_{max}$ should equal approximately 0.3524 inch.

If there are no x or x^3 terms in the equation for ${}_c y$, both the equivalent cam and valve velocity curves for the opening and closing sides will meet at $x/x_r = 0$. If ${}_o y'' = {}_c y''$ at $x = 0$, and there is no x^4 term in the equation for ${}_c y$, both the equivalent cam and valve acceleration curves for the opening and closing sides can also be made to join at zero.

Evaluation of the coefficient for the x^2 term is the first step. When $x/x_r = 0$,

$${}_c y'' = {}_o y'' = \frac{2\, {}_o C_2}{{}_o x_r^{\,2}} = \frac{2\, {}_c C_2}{{}_c x_r^{\,2}}$$

$${}_c C_2 = {}_o C_2 \frac{{}_c x_r^{\,2}}{{}_o x_r^{\,2}}$$

Substituting known values gives

$${}_c C_2 = -\,0.5255719 \frac{(63)^2}{(60)^2} = -\,0.5794430$$

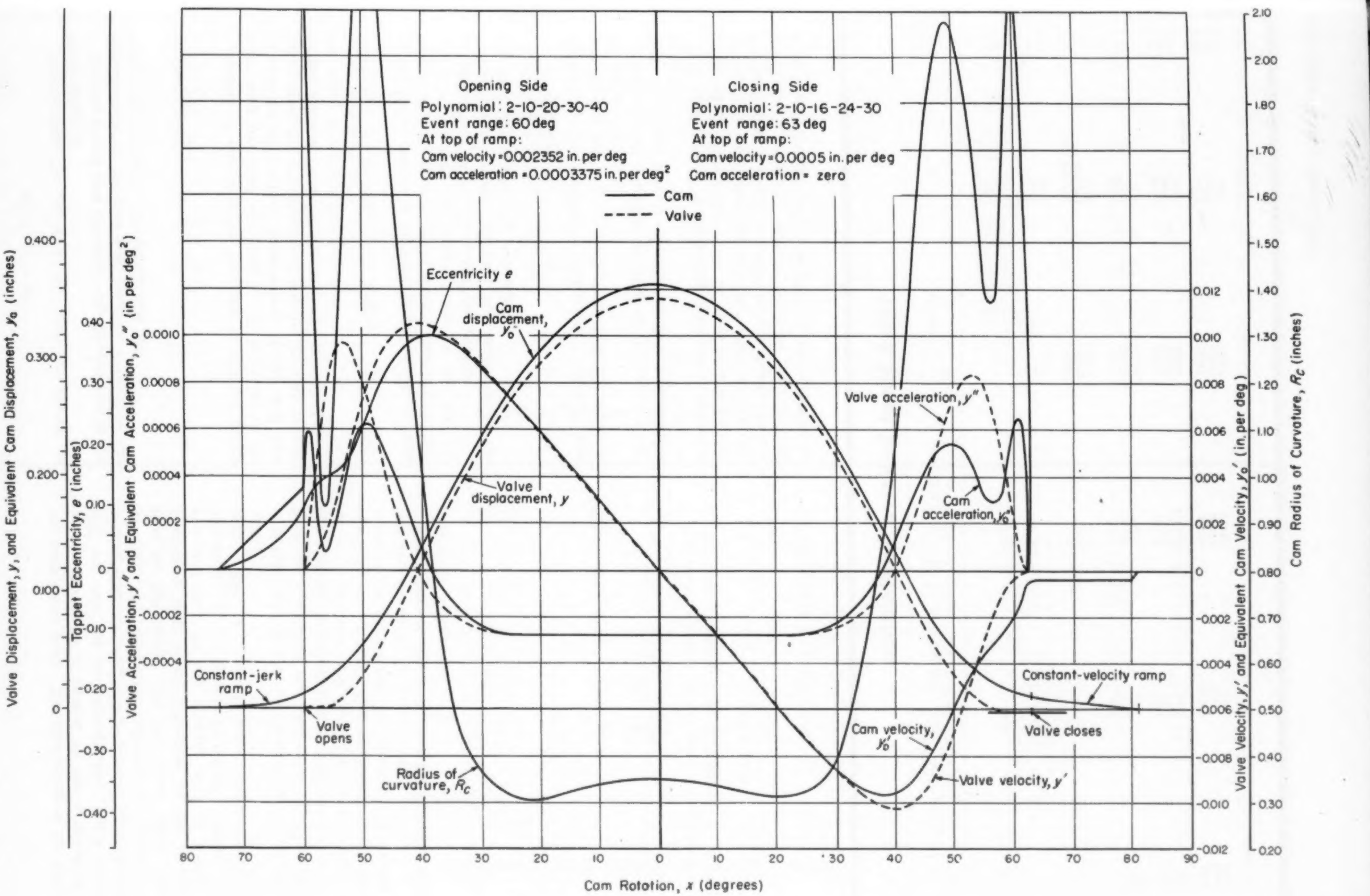
The velocity factor at the junction of cam and ramp on the closing side is next determined:

$${}_c V = \frac{{}_c v\, {}_c x_r^{\,3}}{\phi} = \frac{-\,0.0005(63)^3}{15} = -\,8.3349$$

From TABLE 1 of this article

Work Sheet 5—Valve Acceleration

$\frac{x}{x_r}$	y''	$+\,0.0070817\left(\frac{x}{x_r}\right)^8$	$-\,0.0162311\left(\frac{x}{x_r}\right)^{18}$	$+\,0.0132673\left(\frac{x}{x_r}\right)^{28}$	$-\,0.0038259\left(\frac{x}{x_r}\right)^{38}$
0	−0.0002920	....			
0.10	2920				
0.20	2920	....			
0.30	2915	5			
0.40	2874	46	....		
0.50	2644	277	1		
0.60	−0.0001747	1189	16	....	
0.70	+0.0000904	4082	264	6	....
0.75	3296	7090	915	42	1
0.80	6286	11881	2924	257	8
0.82	7488	14476	4560	512	20
0.84	8552	17554	7037	1006	51
0.86	9342	21190	10748	1944	124
0.88	9695	25468	16257	3701	297
0.90	9447	30484	24362	6943	698
0.92	8479	36345	36185	12848	1609
0.94	6776	43168	53290	23462	3644
0.96	4516	51087	77845	42304	8110
0.98	+0.0002100	+0.0060248	−0.0112828	+0.0075355	−0.0017755
1.00	0				


Opening Side
Polynomial: 2-10-20-30-40
Event range: 60 deg
At top of ramp:
Cam velocity = 0.002352 in. per deg
Cam acceleration = 0.0003375 in. per deg²
Closing Side
Polynomial: 2-10-16-24-30
Event range: 63 deg
At top of ramp:
Cam velocity = 0.0005 in. per deg
Cam acceleration = zero
Cam
Valve
Eccentricity e
Cam displacement, y₀
Valve displacement, y
Valve acceleration, y″
Cam acceleration, y₀″
Constant-jerk ramp
Valve opens
Radius of curvature, R_C
Cam velocity, y₀′
Valve velocity, y′
Constant-velocity ramp
Valve closes
Valve Displacement, y, and Equivalent Cam Displacement, y₀ (inches)
Tappet Eccentricity, e (inches)
Valve Acceleration, y″, and Equivalent Cam Acceleration, y₀″ (in per deg²)
Valve Velocity, y′, and Equivalent Cam Velocity, y₀′ (in. per deg)
Cam Radius of Curvature, R_C (inches)
Cam Rotation, x (degrees)

Fi
va
de

$$ {}_cC_2 = \frac{-qrst\,{}_cy_{max} - (q+r+s+t-6)\,{}_cV + A}{(q-2)(r-2)(s-2)(t-2)} $$

This equation can be rearranged to yield a solution for ${}_cy_{max}$:

$$ {}_cy_{max} = \frac{-(q-2)(r-2)(s-2)(t-2)\,{}_cC_2 - (q+r+s+t-6)\,{}_cV}{qrst} $$

from which factor A has been dropped since it is zero with the uniform-velocity ramp employed on the closing side.

The problem now is to select values for powers q, r, s and t that will give ${}_cy_{max} = 0.3524$ with the aid of the immediately foregoing equation. The first set of values tried are $q = 10$, $r = 14$, $s = 20$, and $t = 28$.

$$ {}_cy_{max} = \frac{-8(12)(18)(26)(-0.5794430) - 66(-8.3349)}{10(14)(20)(28)} $$

This result and successive trials show:

Powers	${}_cy_{max}$
10-14-20-28	0.33907
10-16-24-30	0.35373
10-16-22-28	0.34983
10-16-22-30	0.35238

The final trial with powers 10, 16, 22 and 30 yields a sufficiently accurate approach to the desired value, 0.3524-inch.

Coefficients for the new powers on the closing side are established from TABLE 1 in the same manner as those on the opening side. In all calculations, ${}_cy_{max} = 0.3524$ is used except in the addition of horizontal rows containing ${}_cy_{max}$. Then the value for ${}_oy_{max}$ is used. The result, of course, is that the valve appears to close below the axis, and negative values occur at the end of the lift curve. It should be recalled that the "length" of the linkage is shorter at the top of the ramp on the opening side because of dynamic loading from the ramp, whereas there are no dynamic forces at the constant-velocity closing ramp.

Since the calculations for the closing side are quite similar to those for the opening, the equations and computations are not detailed here. The results appear, of course, in *Fig.* 12.

With respect to the calculation of results for specific degree positions of cam rotation, rather than even values of x/x_r, a comparison of the same equation in both forms might prove helpful. The lift equation on the closing side, in terms of x/x_r, is:

$$ {}_cy = 0.350 - 0.5794430\left(\frac{x}{{}_cx_r}\right)^2 + 0.5631428\left(\frac{x}{{}_cx_r}\right)^{10} - 0.4861947\left(\frac{x}{{}_cx_r}\right)^{16} + 0.1994991\left(\frac{x}{{}_cx_r}\right)^{24} - 0.0493802\left(\frac{x}{{}_cx_r}\right)^{30} $$

But, if values of x in degrees are to be substituted, the foregoing equation should be modified by the substitution of ${}_cx_r = 63$ deg and the combining of this term, raised to the indicated powers, with the numerical coefficient of each power term. Then, the same equation is:

$$ {}_cy = 0.350 - 0.1459922(10)^{-3}x^2 + 0.5717590(10)^{-18}x^{10} - 0.7895169(10)^{-29}x^{16} + 0.1305473(10)^{-43}x^{24} - 0.5168165(10)^{-55}x^{30} $$

Additional Factors: The foregoing example has highlighted most of the significant details of the polydyne procedure. However, further commentary on some points may be helpful.

At times, an additional design criterion can be called into use: the area beneath the displacement curve of the end element. In automotive work, this factor is a useful index of the "breathing" capacity of a valve system. Mere integration of the displacement equations for several trial designs will yield areas that can be compared in relation to other properties of the several designs. Maximum areas are, at first glance, most desirable for valve applications but, on the other hand, dynamics of such a design may be unfavorable.

Area under the displacement curve can be used in still another way. After preliminary exploration, an area factor can be set as one of the requisites of design. Then, the displacement equation can be integrated, another power term added to accommodate the extra condition, and the area equation equated to the desired area. In automotive work, use of an area factor generally produces an unnatural acceleration curve in the negative region and corresponding poor conditions for the cam radius of curvature. However, it does have the advantage of yielding a somewhat lower maximum acceleration with a relatively large area beneath the curve.

Another factor with polydyne cam design is the facility with which the system loading can be determined. Actual loading at design speed can be easily found from the spring rate of the system and the difference between equivalent cam deflection y_0 and end element deflection y (minus clearance).

Application of the polydyne methods to constant-speed cam systems is particularly beneficial. As *Fig.* 3 shows, vibration amplitude is zero at the selected constant speed (design speed). Another interesting point is also brought out by *Fig.* 3. At zero or very low speed, the end element acceleration curve would be the same as the equivalent cam acceleration curve. As the speed is increased, the end element acceleration curve changes until, at design speed, it attains the form established by the equation for y''. Beyond design speed, the end element acceleration curve rapidly deteriorates and vibration amplitude increases. Therefore, if the cam were so designed that its acceleration were described by y'' (instead of y_0''), the acceleration of the end mass would go "out of control" beyond zero speed. Vibration amplitude would increase beyond zero speed in somewhat the same manner as beyond design speed in *Fig.* 3.

The equation presented in the example for radius of a cam curvature is for flat-face followers only. Dud-

Fig. 12—Complete design graphs of automotive valve example. Accompanying work sheets show details of many of the required calculations

ley* has established an equation for radius of cam curvature with a roller follower. Equations that are directly applicable in polydyne cam design for other types of followers may need to be developed.

Significance of the fourth derivative of the end element displacement has been demonstrated in this article. It, of course, directly influences the equivalent cam acceleration. Occasionally, the fifth derivative has also been used. It is directly related to the equivalent cam jerk and requires, of course, an additional power term in the equations. Automotive cams have been so designed with some success, but whether the additional work was justified by certain slight benefits is doubtful. Actually, in automotive cams of usual size, the influence of the fifth derivative control appeared in the fifth decimal place only.

Conclusion: From the foregoing example two things of different virtue emerge: (1) The calculation procedure seems to be complicated and tedious, and (2) properties of the end-element and of the cam are most certainly different. In a sense, one justifies the other.

If the polydyne method is undertaken as a regular program in design, methods here outlined can be systematized and simplified as personnel become familiar with basic procedures. A desk calculator and the work-sheet techniques may prove entirely adequate in many circumstances. However, if extended series of calculations are undertaken, then other time-saving methods might best be adopted. At Thompson Products, tabulating equipment (IBM) was adapted to the work of calculating points on the various displacement and derivative curves.

Additionally, the table of powers given in the first article of this series may prove inadequate because of the limited range of powers or number of places. More complete power tables in volume form are available. One such book is ***Mathematical Tables, Vol. IX, Table of Powers,*** published for the Royal Society at the University Press, Cambridge, England, 1950.

In view of the obviously more laborious nature of polydyne cam design, in contrast to the direct methods employed with conventional functions, one might ask: Is the method of enough value to warrant the effort? The answer lies in the design itself.

No question remains in at least the automotive field. Value received from the method in contrast to past difficulties and compromises has already led to acceptance of polydyne cam design by several automotive manufacturers.

But, perhaps some physical criterion may serve to generally rate the utility of the method. That criterion might simply be the separation of the two displacement curves. The foregoing example has shown how the displacement curve for the equivalent cam departs from the corresponding curve of the end element.

Observation of ***Fig.*** 12 shows that the maximum distance between the two displacement curves is 0.026-inch; the average separation is about 0.012 inch. At the actual cam, because of the rocker arm ratio of 1.5, these distances are 0.017-inch and 0.008-inch respectively. These values are quite significant, whether compared with the maximum displacement (0.350/1.5 = 0.233-inch) or with the acceptable range of error in the manufacture of cams. Commercial quality cams are produced with a total tolerance of ±0.001-inch and a permitted spread at adjacent one-degree increments around the cam of not more than ±0.0001-inch.

Although separation of the two displacement curves in relation to cam manufacturing tolerances may not be a precise index of the probable value of the method, it is adequate as a rough guide. A more critical investigation might be made in terms of system clearance, spring factor ρ, and dynamic factor ϕ. Approximate evaluation of these terms would reveal the specific sources of significant separation of the displacement curves as well as facilitate a study of the effects of redesign of any of the system components, in advance of a full-stage cam calculation.

*Winston M. Dudley—"New Methods in Valve Cam Design," *SAE Quarterly Trans.*, Vol. 2, No. 1, January 1948, Page 19.

Work Sheet 6—Equivalent Cam Displacement and Acceleration

	$y_0 = 0.010976 + 1.015\,y + 15\,y''$			$y_0'' = 1.015\,y'' + 15\,y^{iv}$		
$\frac{x}{x_r}$	y_0	$+1.015y$	$+15y''$	y_0''	$+1.015\,y''$	$+15\,y^{iv}$
0	0.361846	+0.355250	−0.004380	−0.000296	−0.000296	
0.10	356512	349916	4380	296	296	
0.20	340508	333912	4380	296	296	....
0.30	313829	307241	4373	294	296	+0.0000002
0.40	276592	269927	4311	284	292	8
0.50	229177	222167	3966	243	268	26
0.60	173294	164939	−0.002621	−0.000107	−0.000177	71
0.70	114187	101855	+0.001356	+0.000222	+0.000092	131
0.75	86807	70887	4944	446	335	+0.000111
0.80	63384	42979	9429	608	638	−0.000030
0.82	55474	33266	11232	621	760	140
0.84	48451	24647	12828	583	868	285
0.86	42263	17274	14013	494	948	455
0.88	36779	11261	14543	355	982	627
0.90	31804	6658	14171	198	959	761
0.92	27121	3426	12719	79	861	782
0.94	22566	1426	10164	86	688	602
0.96	18158	408	6774	287	458	−0.000171
0.98	14174	+0.000048	+0.003150	584	+0.000213	+0.000371
1.00	0.010976	0	0	+0.000338	0	+0.000338

QUALITY CONTROL METHODS

Their Use in Design

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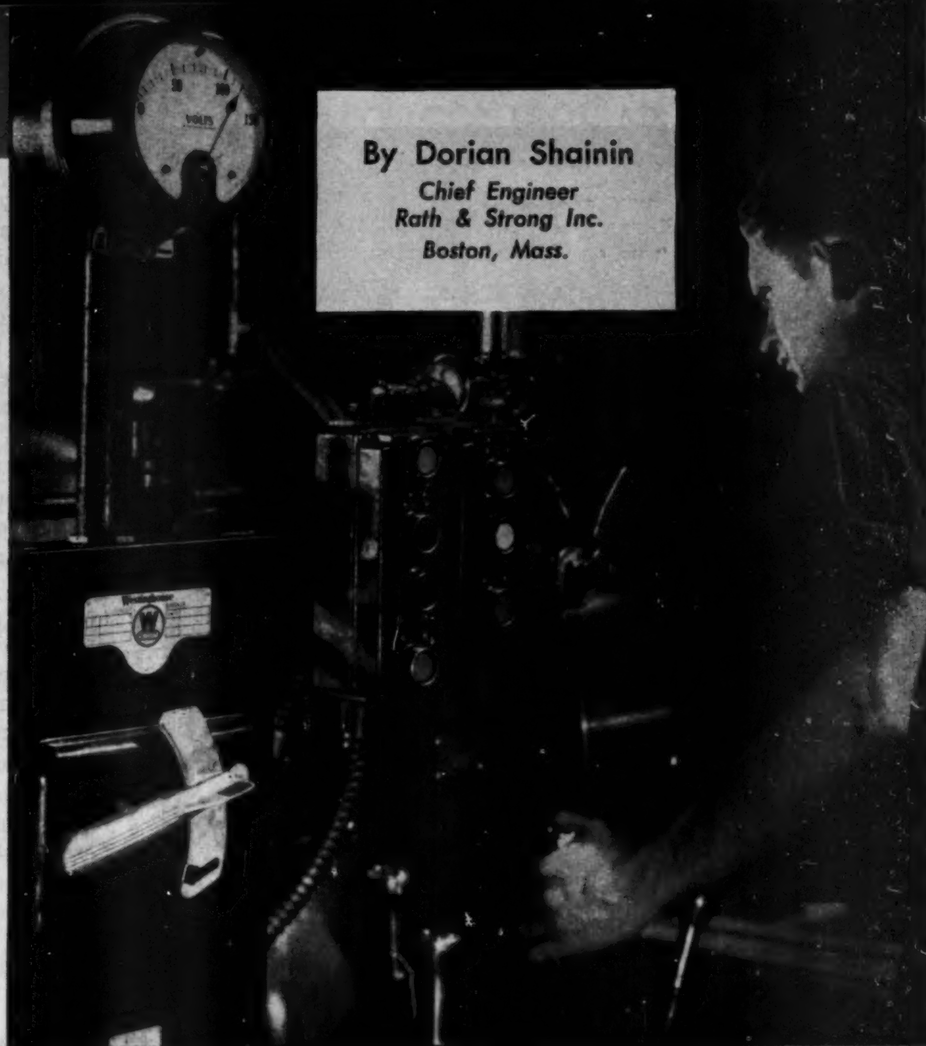
Even the "best" natural tolerances can often be reduced by analysis of the component parts of the total variation



Part 9—Trouble-Shooting Design Defects

Fig. 49—Control charts can be used to eliminate assignable causes of more than inherent variation in a machine design

BRIEFLY stated, the basic objective of SQC is the prevention of defects and all else is secondary. The designer should try to put into his machine design an ability to function only within acceptable limits. He must know how causes of difficulties can be most readily found. Experience along these lines will make him a better designer.

Stage one of the subject has been touched upon in the preceding articles: at times machine capability can be statistically determined to be less than specification allowances; and it can be kept at its minimum spread by using a control chart. This article will enter upon two further stages of analysis that can be very helpful when trouble develops. Trouble here means a situation that does not resolve itself by the application of a control chart or of a Lot Plot. The chart keeps out assignable causes of more than the inherent variation in a machine design and warns of changes, *Fig.* 49. The Lot Plot can reveal distributions that are out of position or that contain more than one pattern (multimodal histograms).

The "Out-of-control" Case: This is stage two of the three methods. As an instance, suppose a sum and range chart shows some points beyond control limits. Further, assume that all of the usual steps to correct the process or machine variation have been taken; ones that have been successful in the past for similar cases. If none of these trials brings results, even

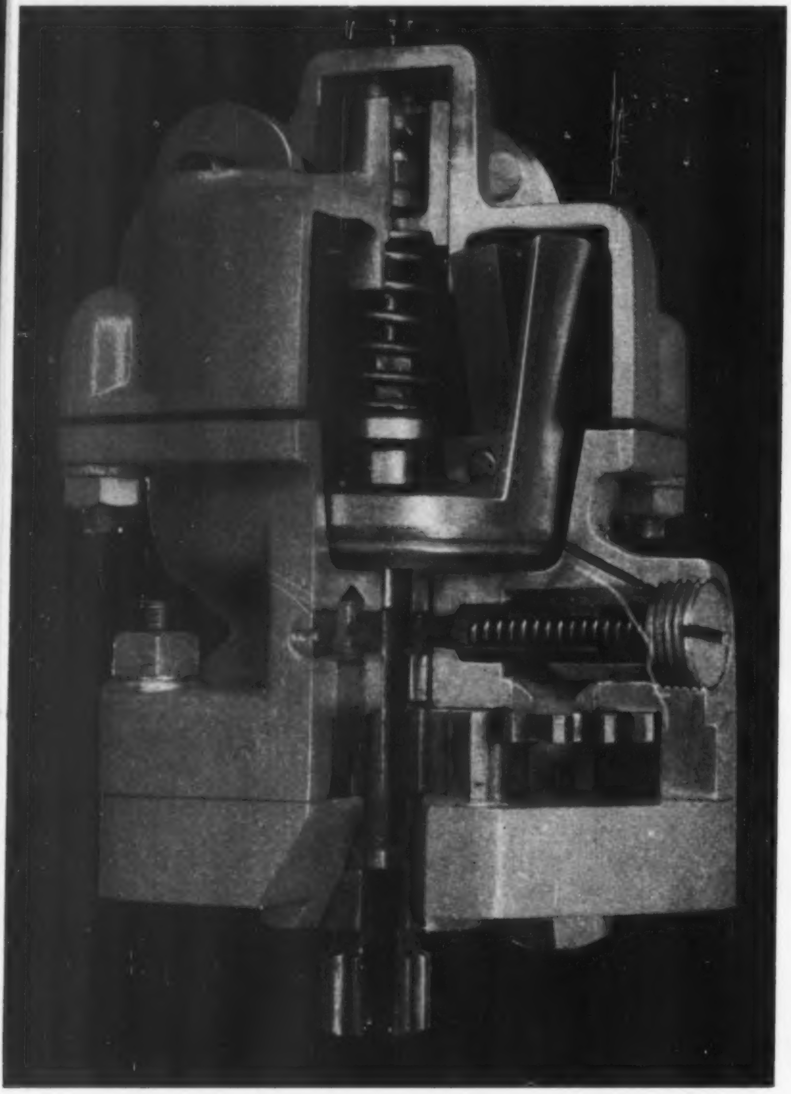


Fig. 50—Inherent or expected variations in the performance of a mechanism such as this governor unit can be reduced or minimized by SQC methods

with one or two new ideas, some real trouble-shooting is necessary.

To track down an assignable cause of extra variation, start by listing all suspected causes of such variation. Then, devise a method to measure each suspected cause and take thirty readings of each, making sum and range charts with subgroup sizes of three. For each case of all the points falling within the control limits, cross out that suspected cause from your list. Readings that vary in accordance with pure chance stand for a condition that normally will have only a pure chance effect, if any at all, on a subsequent result. Such a reading will not prove to be an assignable cause.

If, in any trial, all the points do not lie within the control limits calculated from the suspected data, then, more likely than not, that cause is assignable. Appropriate steps must then be taken to bring the variation back into a chance pattern. One such step could be using a control chart for the next production run and then recharting the final results to confirm that all assignable causes have left.

Improving an Operation Within Control: When a control chart shows an operation is running within statistical control, the "best" apparent results are being obtained from the combination of machine, material, and control. Only inherent variables exist; no causes of extra variation are acting to make the spread of readings or natural tolerance any larger than it need be.

It is of particular interest to the designer that this "best" can be made better, *Fig.* 50. By a third basic stage of analysis of the situation, natural tolerances can often be reduced.

Although the variation is an inherent characteristic of the operation, the total built-in variation can be broken down into components in order to check the relative magnitude of each. Usually one or, sometimes, two parts contribute to a much greater extent than the others to the total variation. This fact may be the much needed clue to lead a trouble shooter to that part of the problem where effort can be most rewarding.

Considering in general terms any sort of an operation—forming a dimension on a piece, heat-treating a lot of material in one or more furnace loads, or processing chemicals in some sort of a solution, etc.—it is appropriate to term the item on which the variation is to be checked as a "batch", even though the word piece or unit might be more appropriate in the machine design field.

Total variation should be separated into three components. The first is the variability within the batch. In a solution it may be the result of improper mixing, while mechanically we could be talking about out-of-round, taper, or variation in hardness throughout a piece. Errors in measurement also can contribute to this within-piece category. To assess its magnitude more than one reading is necessary from each batch or on each piece in different regions.

Another component can be batch-to-batch variability: the difference between one unit of product and the next. One end of the rod of raw bar stock, from which several parts will be cut, can differ from the other. Machine adjustment difficulties of one type or another or using different starting points tend to increase this piece-to-piece variation.

Time-to-time variability comprises the last major component for this breakdown. Tool wear, different operators, the raw material varying among lots, or other such long-term circumstances bring about this sort of variation.

The Multi-Vari chart, *Fig.* 51, graphically portrays the relative magnitude of these three components, not only with respect to each other but also to the allowable spread between specification limits.[1] To understand this diagram imagine a simple situation, the turning of the outside diameter of a cylindrical piece. The left-hand scale would represent diameter sizes, going from just below the lower to just above the upper specification limit. Three or four measurements are made on the diameter of each piece turned on the lathe. Each heavy vertical mark shows the range of readings from one piece of product. The smallest diameter measured on that piece lies at the bottom of

[1] References are listed at end of article.

the mark while the top of the line stands for the largest. So the length of the line represents the amount of out-of-round. You can, by eye, estimate the position of the center of each of these lines as the average diameter.

Besides out-of-round, the length of lines can serve to indicate many other forms of "within-batch" variation. Taper and nonuniform hardness per piece were mentioned before. Others are thickness and misalignment variations found as out-of-parallel, eccentricity and out-of-square readings.

Referring to the left-hand section of the chart—Type I condition, excessive variability within batches—the piece-to-piece variation (from the center of one line to each other mid-point) is extremely small in comparison to the distance between specification limits. Time-to-time variation in this same section is also small, the situation at 9 am being not radically different from that at 10 am when five additional pieces were measured, etc. The large amount of out-of-round per piece, within-piece variation, however, runs to about 120 per cent of the maximum tolerance allowed.

The middle section of the chart illustrates a large Type II component, the change from batch-to-batch or piece-to-piece being excessive. The out-of-round accounts for only about thirty per cent of the tolerance, while the differences among the centers of the lines use up virtually 100 per cent of the permitted spread. Time-to-time is again small. At each hour the picture closely duplicates itself.

The third example shows quite acceptable within-piece as well as piece-to-piece variation. Too much of the tolerance is taken up by the scatter of time-to-time results.

If the Multi-Vari chart looks something like the Type I case, then the operation of the machine should be diagnosed for clues among the things that can cause out-of-round. It might perhaps be a misaligned chuck or spindle, an eccentric bearing, or insufficient rigidity of part of the machine or the work itself. Adjustments or design changes can be made that would be suggested by these clues.

As each alteration is tried, another Multi-Vari chart can be run for checking the new results. If all of the lines shown in the Type I case measurably shorten but now seem to be running so that their center points are all about half way between the middle and the upper specification limit, it will be known that the correction has primarily been successful. But now the setting needs to be reduced somewhat to bring all the material well to the middle of the chart.

If, instead, the chart takes on the appearance of Type II, great batch-to-batch variability, then look for things that can make one piece, motion, etc., quite different from the next. In the case mentioned, nonuniform chucking, too much change in the amount of material to be removed, a loose tool, etc., might be suspected.

The large time-to-time pattern shown as Type III could perhaps lead to such findings as excessive hardness differences among groups of incoming raw material, or gradual changes in the coolant used or the lubricant employed.

Both before using a Multi-Vari chart and after making successful changes, a control chart could still run in control. With a basic change having been made in the process or design, the second chart will show a reduced natural tolerance.

Where to Trouble Shoot? When an uncomfortable percentage of end product has an undesirable characteristic, or one that is running beyond limits, it may or may not be clear which step in the process is directly contributing to the trouble. When it is known exactly *where*, but not *what* the trouble is, one of the three steps just described serves to bring about the

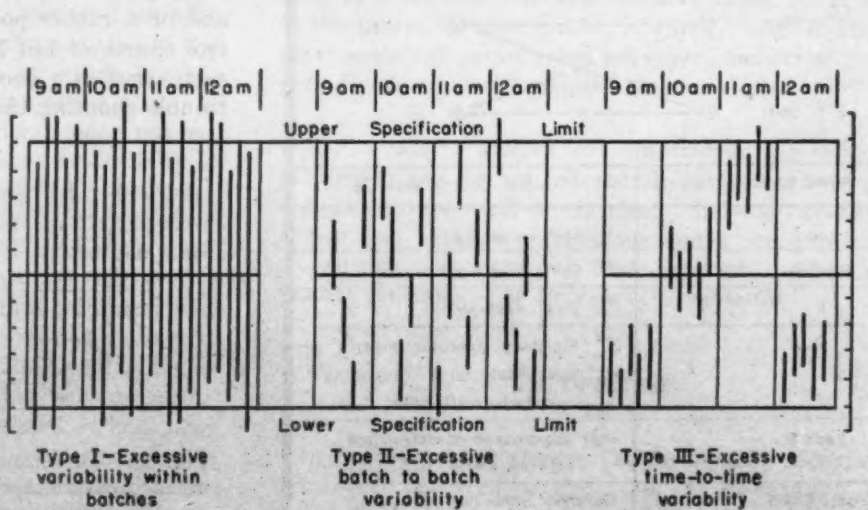


Fig. 51 — A Multi-Vari chart shows the relative magnitude of the component parts of the total built-in variation of an operation or function

necessary correction. But there are times when several operations may quite reasonably be singly or jointly suspected, and other supplementary aids may be effective.

Relatively straightforward steps can localize the difficulty when the final property or characteristic involved can be measured during the process of manufacture. An example might be a finished plated product found to have a high rate of rejection for magnetic-particle test indications brought about by cracks in the material. Magnetic testing of parts both before and after the plating operation indicates that the rate of rejection is significantly greater after as compared with before plating. Hydrogen embrittlement commonly results with such a plating process and is particularly troublesome above a certain hardness of material.

The usual solution is to relieve the embrittlement by a furnace treatment directly following the plating. But here, for some reason, the trouble occurs so soon after the plating process that there is not time enough to relieve it sufficiently to cut down the incidence of cracking. The problem then becomes: which of the many previous machining or grinding operations might be "abusing" or "prestressing" the material to such an extent that the adsorption of hydrogen on the surface of the part during plating quickly leads to cracking?

To resolve this problem samples of semifinished pieces after each operation could be brought to the plating bath. Results of magnetic-particle tests following the plating would show clearly which step or steps were responsible. Once discovered, the next move would be to change feeds, speeds, grit of wheel, or the like until a combination was found that would not result in such destructive action before the hydrogen-embrittlement relief could take care of the plated pieces.

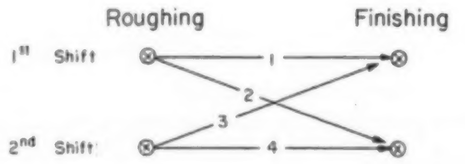
Parallel Paths: Sometimes more than one production line turns out similar articles. More often just one or two of the several operations on a product can take place on duplicate fabrication equipment. So an item of product may take one of several paths. When more than one operator runs a machine, as in the case of multishift operation, the work that is handled by one operator may be said to follow a different path than that handled by the other shift worker.

Lot Plots or control charts can be run after each of various steps of a parallel-path operation in order to pinpoint the particular operator or piece of equipment that might be contributing to the difficulty. But other characteristics of such duplicate work need to be considered in this use of statistical analysis. Picture a roughing followed by a finishing operation. Normally, it may not be the case that pieces at the end of the line followed only one of two paths, if single production machines with two-shift operation were employed. Some of the second-shift roughing may be finished on the first shift and vice-versa along with work that followed entirely on one shift.

One logical approach might be to see whether the natural tolerance of each roughing "machine-operator" is not too variable. There may be too much difference among the "starting points" for finishing. But as a real aid to this problem earmarking of certain pieces in advance to follow given paths can be tried. Then the results can be correlated with the particular culprit, which may be any one of the four machine-operator combinations: the roughing operation with either one of its two operators, or the finishing with its two-shift workers. Still other sources of trouble may be indicated, as in *Fig.* 52.

As a general rule, with several items of similar fabrication equipment, or several operators doing the same job, almost always a rather good performer and/or a rather poor performer can be found. Control charts or Lot Plots that show the capabilities of each serve as a good first step to pick them out. The trouble shooting then consists of attempting to deter-

Fig. 52—Typical clues that might be investigated when material moves along four separate paths



Only Paths Showing Trouble	Trouble Source May Be
1 and 2	1st Shift roughing
2 and 4	2nd Shift finishing
1	1st Shift supevision
2	2nd Finishing operator doesn't compensate for 1 roughing operator's difficulties
2 and 3	Poor coordination of instructions between shifts
1,2,3 and 4	Equipment rather than operators, but there are other possibilities

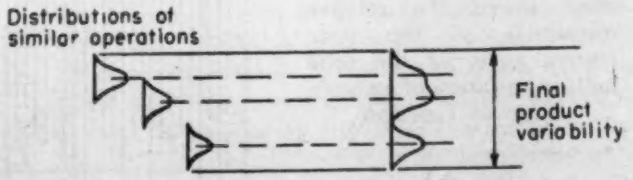


Fig. 53—Different capable operators or different acceptable machines doing the same job can result in this type of mixed output, too wide to meet specifications

mine what needs to be done to the poor machine or operator to return the performance level to more nearly average. And even more important would be an investigation to find out why the best one is that good. A discovery here could lead to a most worthwhile change to all the other machines or operators.

As another characteristic of such multipath operations, the large variability found in the final product may not be traced to a great variability in any one step of the process. Instead, there may be similar operations that differ in their average position, even though their spreads are acceptably narrow. A mixing of the different averages produces a final output of much greater variability, as shown in *Fig.* 53.

In some cases the performance at any one step of a process is not measurable, but can only be counted in terms of good and bad material, or good and bad areas on the item of product. Then the standard attribute control charts of the *p* or the *c* type are the effective tools for statistical analyses.

Characteristics Only in the Final Product: Some processes can not be considered as made up of steps between which you can measure an effect on the desired final property or dimension. The property in question may not exist until a series of operations has taken place. The operating characteristics of an hydraulic pump, an electric motor, or an electronic vacuum tube are not things that can be handled by the procedures so far described.

First characteristic to seek is one that may be related to the final one but which itself may be measured at various steps of the process. Examples might be the clearances in the pump as determined by the dimensions of two mating parts, or the electrical characteristics of the field and armature windings in the electric motor.

Failing this approach parallel paths may be found or even created by adding some processing equipment, perhaps in the laboratory or in experimental operations. With this arrangement a small sample can be taken from the production streams at each of various steps of the process. Finishing of the sample parts can then be done using the parallel-path equipment. Comparisons between the product coming from the normal path and that bled off at various stages of the process should point to the stage at which trouble first "appeared" in the shunted-off sample.

If a particularly elusive relationship does not reveal itself by any one of the methods described, all is not lost. Two other techniques, extremely powerful in their analytical value, are available. Unfortunately they are beyond the scope of a series of articles such as this, but the interested reader can secure two excellent references. One is correlation analysis[2] and the other is analysis of variance.[3] These methods permit the design of experiment mathematically to hold "constant" all other factors while the particular relationship being studied can be assessed. These procedures are much more economical than the classic plan of attempting to hold all variables physically constant while varying the one of primary interest. Actually these methods become the only practical solution since it is virtually impossible to hold any number of pertinent things really fixed while going through the experimental tests. It must of course be emphasized that such more involved statistical approaches should be applied only when the more straightforward trouble-shooting steps described previously fail to show clearly and much more simply where your difficulty may lie.

Most of the work in correlation analysis and in analysis of variance has come from research in biology, genetics and agriculture. But the trouble-shooter will find that he can profitably use these same techniques in solving some of the problems of the mechanical designer.

The phrase "trouble shooting" has been used liberally in this part of the series. It should now be clear that we are referring to a practice that may carry many another label. Whatever the name, it can profit from the application of the scientific method involving statistical analysis, whether the work be in the laboratory, in production engineering, in inspection, or in quality control. The latest name for a conglomeration of the various useful techniques and an extension of the program beyond mere trouble shooting, shall we say, is called Operations Research. The next and concluding part of this series will discuss this latest and most interesting development in methodology.

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2. Ezekiel, Mordecai—*Methods of Correlation Analysis*, Second Edition, John Wiley and Sons, Inc., New York, 1945.
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They say . . .

"American industry has a world-wide reputation for building quality products. Perhaps they are sometimes too good, in the sense that they still have a high percentage of their life left when they are obsolete. With the supply of many of our essential materials of construction critically short, we need to take a very careful look at our production picture to establish whether we have, in our designs, the proper mix and type of materials that will conserve those which will, in the future, be most critical of supply."—F. R. BENEDICT, *assistant engineering manager, industrial products divisions, Westinghouse Electric Corp.*

". . . research science has outstripped the capacity of the solitary worker. Research, in plain words, has become too involved, too intricate, and too expensive. A few test tubes, a microscope and a machine shop are no longer enough to do basic research."—NEIL MCELROY, *president, The Procter & Gamble Co.*

Correction

In the December article, "High-Capacity Gearing," two errors occurred on Page 139. In Equation 5, the constant should be 12.9 instead of 9.7. Also, in the Nomenclature on Page 139, pitch angle of the bevel pinion should be identified as tan $\gamma = D_P/D_G$ instead of D_G/D_P.

MULTISTAGE SEALING

. . . for rotating shafts operating at elevated pressures and temperatures

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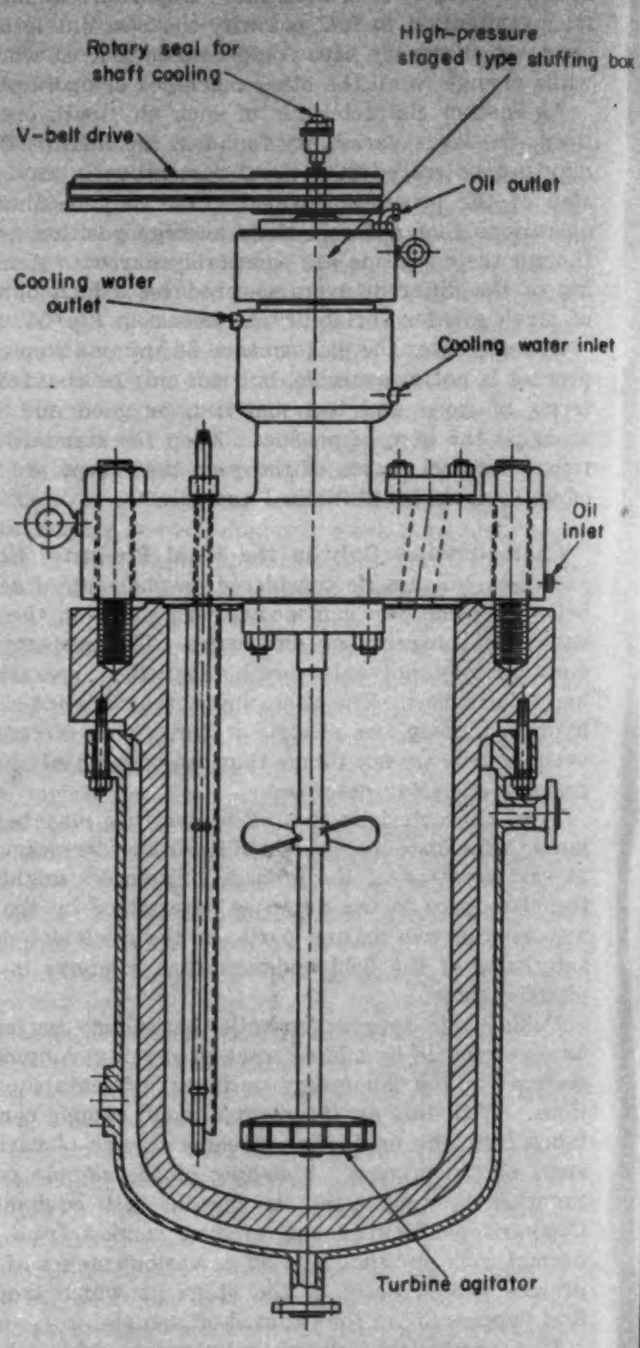


Fig. 1—Stuffing box employed to seal agitator shafts on high-pressure autoclaves. This unit must withstand pressures of 3000 to 5000 psi and temperatures of 300 to 600 F

SEALING a rotating shaft against pressures to 5000 psi at temperatures to 600 F demands more than ordinary means of sealing. How multistage sealing can be effectively applied under such service conditions is demonstrated by the autoclave design shown in *Figs.* 1 and 2. Experimental models of the stuffing box have been successfully operated at pressures of 10,000 psi and higher.

Design Objectives: For sealing rotating shafts against pressures of 200 to 300 psi, the rotary mechanical seal is generally satisfactory and, when properly run in, gives long service life. However, if the limitations of the mechanical seal are exceeded, some form of packing becomes necessary. The use of packing in a stuffing box to seal rotating shafts entails recognition of two basic factors: first, the packing will eventually fail and second, the portion of the shaft in contact with the packing will wear. Therefore, consideration must be given to the rapid and easy replacement of worn parts.

Maintenance accessibility becomes particularly important in large agitated pressure vessels, such as autoclaves. The portion of the agitator shaft which extends into the vessel may be of large diameter and is often an expensive material. For example, stainless steel or nickel are often specified for corrosion resistance and other properties. In an advantageous stuffing box construction, this section of the shaft would not be disturbed during repacking. Also, if there is no contact between the packing and this shaft section, shaft replacement because of wear will not be required.

Thus, the features to be desired in a stuffing box are long life of packing, minimum shaft wear and ease of maintenance. Experience has shown that in a stuffing box of short length, properly lubricated and sealed against low pressure, packing and shaft life are much greater than for the conventional high-pressure construction which merely employs longer sets of packing to provide necessary sealing. Moreover, in the conventional high-pressure construction, only a few of the packing rings provide sealing and, at the same time, cut deep grooves in the shaft. The longer packing sets also tend to upset, a condition which prevents their functioning equally. For these reasons, equal pressure drops across each packing ring are desirable under high-pressure operation. Bearing pressures exerted on the shaft are then equalized.

Other requirements for satisfactory high-pressure stuffing box life and service are good lubrication and ample cooling. Length of packing sets should permit a small amount of lubricant to seep past on the wearing surface, supplying all rings with an amount ample for hydraulic sealing action. Cooling of shaft and packings must be adequate to dissipate the heat generated by friction.

Design Details: The design of the stuffing box evolved to meet the basic requirements just discussed is shown in ***Fig.*** 2. Self-actuating (self-sealing) packing is used in stages to secure long packing life and minimum shaft wear. Each stage or length of packing is short enough to prevent overturning of the packing rings and operates independently of the others. The only source of pressure applied to the packing is the operating pressure.

To prolong life of wearing parts, an oil system maintains the circulating oil at a pressure 100 to 300 psi above the vessel pressure. Any leakage will thus be toward the inside of the vessel. Also, the differential pressure will not exceed the limitations of the rotary mechanical seal. Furthermore, the outer packing will be subjected to a pressure which is the sum of the vessel pressure and the differential pressure. For autoclave processes, full pressure is usually employed only for relatively short periods of time in "batch" runs. Since the packing is self-actuated by the applied oil pressure, life of the packing is increased.

As oil flows from within the stuffing box, it is returned to an oil reservoir at atmospheric pressure. The pressure drop in the oil system then is the sum

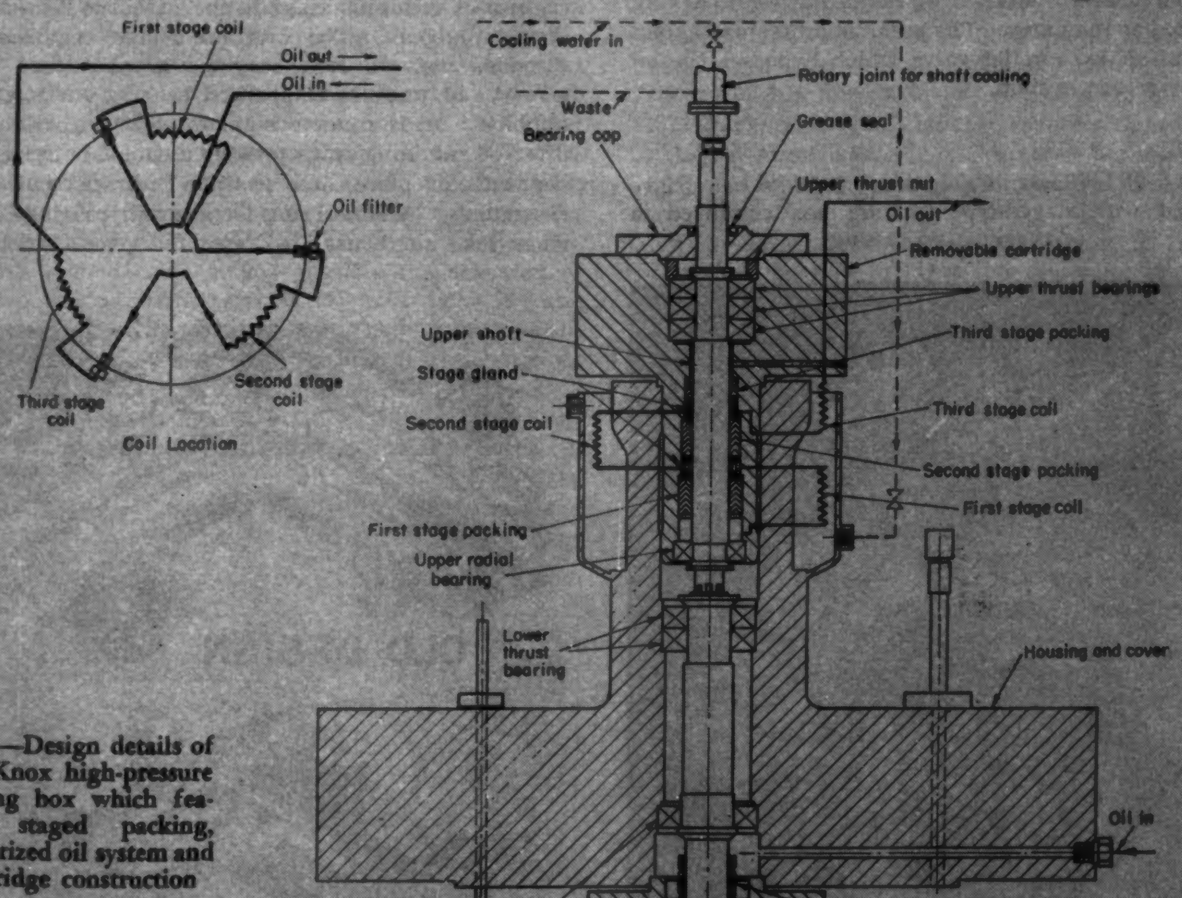


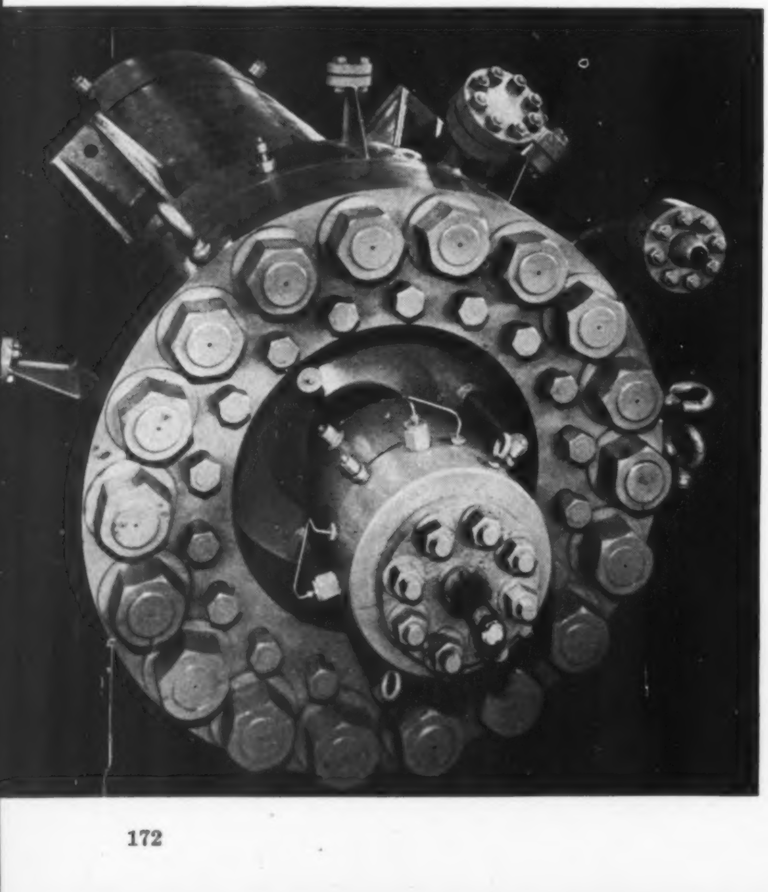
Fig. 2—Design details of Blaw-Knox high-pressure stuffing box which features staged packing, pressurized oil system and cartridge construction

of the autoclave pressure plus the differential pressure. If the inner vessel of the autoclave is operating at 3000 psi and the preset differential pressure is 300 psi, total oil pressure drop through the stuffing box to the reservoir would be 3300 psi. Thus, for the three-stage stuffing box in *Fig.* 2, there would be a pressure drop of 1100 psi across each stage. This measured pressure drop across each stage is achieved with coils of capillary tubing made up in appropriate lengths. These elements act as hydraulic resistors to cause a predetermined pressure drop of the circulating oil across each stage. The last coil reduces the pressure to atmosphere. Coil arrangement is shown in the inset view of *Fig.* 2.

Differential oil pressure is maintained at a preset value above the autoclave pressure by a diaphragm air motor which regulates the delivery of a variable-delivery high-pressure pump. Operation of the air motor is controlled by a differential pressure controller which has for its primary pressure, the autoclave pressure, and for its secondary pressure, the pressure of the circulating oil as it enters the stuffing box. The preset oil pressure differential is maintained from zero to the highest autoclave pressure.

In addition to shaft cooling, the circulating oil is cooled as it passes through each coil of capillary tubing by a water jacket. Also, an oil cooler is provided at the pump. To prevent clogging of the system by stray particles, oil filters are provided at each packing stage and at the pump. The pump is protected against full shut-off by a relief valve which bypasses the oil into the return system.

Fig. 3 — Blaw-Knox 600-gallon, 3000-psi autoclave equipped with staged-type stuffing box employed in chemical processing

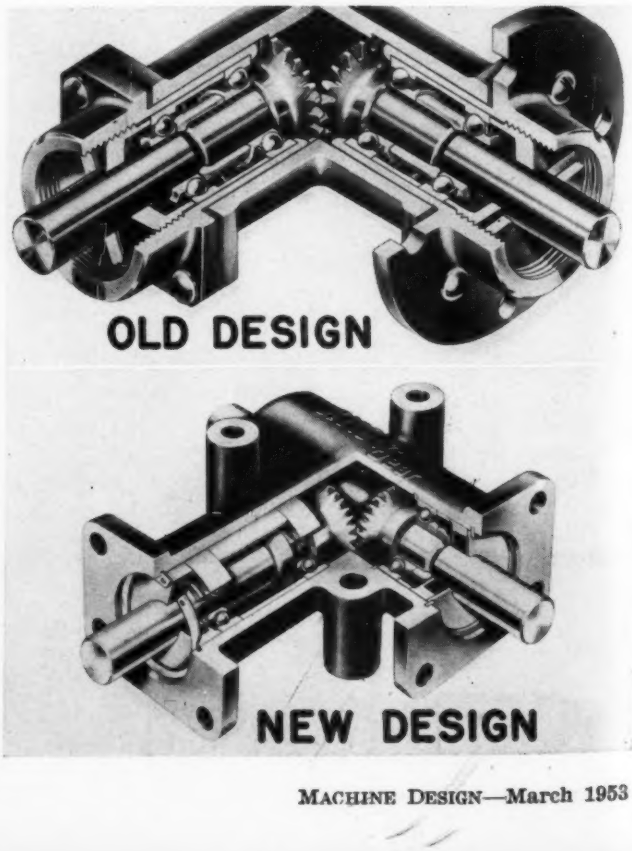


For ease of maintenance, a two-piece splined shaft is used in the stuffing box. The lower part of the shaft is rigidly mounted in the cover of the vessel on antifriction bearings along with the rotary mechanical seal since these parts require only infrequent attention. The upper or driving portion of the shaft is mounted in a readily removable cartridge by antifriction bearings. This cartridge also contains the pressure packing set and the coils of capillary tubing. Removal of the cartridge does not disturb the lower portion of the shaft and parts may be easily inspected and replaced. If continuous operation with minimum interruption is desired, a spare cartridge may be maintained as a standby replacement and repacking of one unit may be accomplished while the other is in service.

This stuffing box design has particular value for use on vessels working with contents which would be hazardous or toxic when freed to the atmosphere. The preset oil pressure differential maintains pressure toward the inner vessel and any leakage from the stuffing box will merely be oil seepage. A typical industrial application of the stuffing box is shown in *Fig.* 3.

Retaining Rings Simplify Design

WEIGHT is reduced approximately 16 per cent and the machining of threads is eliminated by the use of retaining rings in the Airborne Accessories Corp. Anglgear. The original design required two threaded nuts to lock bearings in place and eight screws and washers to position bearing and shaft assemblies. In the new design, three Waldes Kohinoor inverted retaining rings provide a shoulder to lock the bearings in place and position bearing and shaft assemblies. Another ring locates ball bearings. The rings take all thrust load from the gear assembly.



Gear Ratio Logarithms

By George M. Mencke
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Part 2–Combinations for 121 to 150 Teeth

GEAR LOGS, the logarithms corresponding to the ratios of the numbers of teeth in pairs of gears, can often facilitate selection of gear pairs or combinations having the correct number of teeth to produce a desired ratio. TABLE 1, containing all possible ratios obtainable from the numbers 16 through 120 (approximately 3500 ratios), was presented last month, and various methods of application of the table were covered. The accompanying ratios, TABLE 2, include numbers from 121 through 150 in combination with other numbers in that range and also with the numbers from 16 to 120. The highest ratio in TABLE 2 is 150/16; the lowest is 150/149. No ratio of TABLE 1 is duplicated by the approximately 2300 ratios in this table.

This second table makes possible the selection of gear pairs for ratios between $7\frac{1}{2}$ to 1 (120/16) and $9\frac{3}{8}$ to 1 (150/16). Ratios from TABLE 1 with ratios from TABLE 2 may produce more accurate answers than would be possible if only one table were used. Moreover, in combinations, different pairs may contain common multiples that can be cancelled out with a consequent reduction in numbers of teeth in the gears. Metric conversions can be performed using the many gear ratios in this table which include the number 127 (5×25.4 mm per inch).

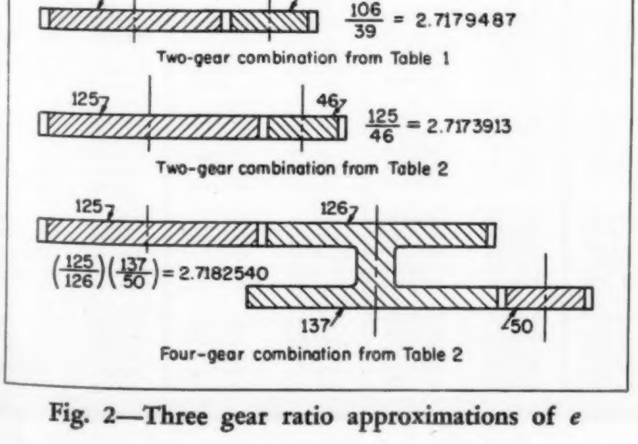

Fig. 2—Three gear ratio approximations of *e*

Values in TABLE 2, of course, are used in the same manner as those in TABLE 1. To illustrate the use of the table, the value for *e*, 2.718218, will be used. The logarithm of *e* is 0.4342945. A single ratio approximation from TABLE 2 is 125/46 whose log is 0.4341522, and which equals 2.7173913. An error of approximately one part in 3000 would result if this ratio were used. In this instance, TABLE 1 contains the ratio 106/39 whose log is 0.4342413 and equals 2.7179487. This result is more accurate than the ratio obtained from TABLE 2. If greater accuracy is required, a two-ratio combination can be selected.

Two Ratio Combination: Employing a technique described in Part 1, that of reversing the driver driven relationship, and choosing one ratio from the low increment portion of the table approaching the ratio one to one, yielded the following two-ratio combination for the ratio 2.7182818 or *e* with only a few trials:

$$\begin{aligned} \log e &= 0.4342945 \\ \log 126/125 &= \underline{0.0034605} \\ \text{log of second ratio} &= 0.4377550 \end{aligned}$$

From TABLE 2, the best value is log 137/50 = 0.4377506. Inverting the first ratio and checking,

$$(125/126)(137/50) = 2.7182540$$

The 125 and 50-tooth gears can be altered, of course, to provide for other possible conveniences in design without affecting the overall ratio. Instead of 125 and 50, for example, 50 and 20 or 45 and 18 might be employed.

This two-ratio combination is in error by less than one part in 90,000. Using a three-ratio combination would probably not result in much greater accuracy in this instance. However, the possibility of achieving higher accuracy with a three-ratio combination always exists. Another point which should not be overlooked is that TABLE 1 and TABLE 2 supplement each other. The most accurate solution will many times result from combining ratios from both tables.

Table 2—Gear Ratio Logarithms for Numbers from 121 to 150

Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log
150/16	.9719713	127/17	.8733548	136/21	.8113196	148/26	.7552884	141/28	.7020611	143/32	.6501860	135/34	.5988549
149/16	.9690663	149/20	.8721563	123/19	.8111515	125/22	.7544873	146/29	.7019549	134/30	.6499835	131/33	.5987574
148/16	.9661417	134/18	.8718323	142/22	.8098656	142/25	.7543483	5/1	.6989700	125/28	.6497520	127/32	.5986537
147/16	.9631973	141/19	.8704655	129/20	.8095597	147/26	.7523440	149/30	.6960650	138/31	.6485174	123/31	.5985434
146/16	.9602329	126/17	.8699216	148/23	.8085339	130/23	.7522156	144/29	.6959645	129/29	.6481917	146/37	.5961512
145/16	.9572480	148/20	.8692317	135/21	.8081145	141/25	.7512791	139/28	.6958568	133/30	.6467303	138/35	.5958111
9/1	.9542425	133/18	.8685791	122/19	.8076062	124/22	.7509990	134/27	.6957410	146/33	.6458390	130/33	.5954295
143/16	.9512160	140/19	.8673744	141/22	.8067964	146/26	.7493796	129/26	.6956164	137/31	.6453589	122/31	.5949981
142/16	.9481683	125/17	.8664611	128/20	.8061800	129/23	.7488619	124/25	.6954817	128/29	.6448120	149/38	.5934027
150/17	.9456424	147/20	.8662873	147/23	.8055895	123/22	.7474824	148/30	.6931404	141/32	.6440691	145/37	.5931663
141/16	.9450991	132/18	.8653014	134/21	.8048855	134/24	.7468936	143/29	.6929380	145/33	.6428541	137/35	.5926526
149/17	.9427374	139/19	.8642612	121/19	.8040318	145/26	.7463947	138/28	.6927211	123/28	.6427471	133/34	.5923727
140/16	.9420080	146/20	.8633229	127/20	.8027737	128/23	.7454822	133/27	.6924878	136/31	.6421772	125/32	.5917600
148/17	.9398128	124/17	.8629728	146/23	.8026251	139/25	.7450748	128/26	.6922367	149/34	.6417074	121/31	.5914237
139/16	.9388948	131/18	.8619988	133/21	.8016323	122/22	.7439371	123/25	.6919651	127/29	.6414057	144/37	.5901608
147/17	.9368684	138/19	.8611255	139/22	.8005921	133/24	.7436414	142/29	.6898903	131/30	.6401500	136/35	.5894709
138/16	.9357591	123/17	.8594562	145/23	.7996402	144/26	.7433892	137/28	.6895626	122/28	.6392018	128/33	.5886961
146/17	.9339040	130/18	.8586709	126/20	.7993405	127/23	.7420759	127/26	.6888304	135/31	.6489721	147/38	.5875337
137/16	.9326006	137/19	.8579670	132/21	.7983546	138/25	.7419391	122/25	.6884198	149/33	.6388221	143/37	.5871343
145/17	.9309191	144/20	.8573325	138/22	.7974564	149/27	.7418225	146/30	.6872316	126/29	.6379725	139/36	.5867123
136/16	.9294189	122/17	.8559109	144/23	.7966347	148/27	.7388979	141/29	.6868211	139/32	.6378648	131/34	.5857924
144/17	.9279136	129/18	.8553172	131/21	.7950520	137/25	.7387806	131/27	.6859075	134/31	.6357431	127/33	.5853898
135/16	.9262138	136/19	.8547853	143/23	.7946082	126/23	.7386427	126/26	.6853972	121/28	.6356274	123/32	.5847551
143/17	.9248871	143/20	.8543060	137/22	.7942979	142/26	.7373150	121/25	.6848454	125/29	.6345120	142/37	.5840866
134/16	.9229848	150/21	.8538720	140/22	.7937053	131/24	.7370601	150/31	.6847296	142/33	.6337744	134/35	.5830368
142/17	.9218394	121/17	.8523365	149/24	.7929751	136/25	.7355989	140/29	.6837300	133/31	.6324899	149/39	.5821217
150/18	.9208188	128/18	.8519375	124/20	.7923917	125/23	.7351822	135/28	.6831758	137/32	.6315706	145/38	.5815844
133/16	.9197316	135/19	.8515802	130/21	.7917241	141/26	.7342458	130/27	.6825796	124/29	.6310237	141/37	.5810174
141/17	.9187702	142/20	.8512583	136/22	.7911162	130/24	.7337322	125/26	.6819367	128/30	.6300887	137/36	.5804181
149/18	.9179138	149/21	.8509670	142/23	.7905605	146/27	.7329891	149/31	.6818246	145/34	.6298891	148/39	.5791971
132/16	.9164539	127/18	.8485312	123/20	.7888751	135/25	.7323938	139/29	.6806168	132/31	.6292122	129/34	.5791108
140/17	.9156791	134/19	.8483512	129/21	.7883704	124/23	.7316939	134/28	.6799468	149/35	.6291183	125/33	.5783961
148/18	.9149892	141/20	.8481891	135/22	.7879111	140/26	.7311547	148/31	.6789000	140/33	.6276141	140/37	.5779263
131/16	.9131513	148/21	.8480424	141/23	.7874913	145/27	.7300042	124/26	.6784484	123/29	.6275071	121/32	.5776354
139/17	.9125659	7/1	.8450980	122/20	.7853298	134/25	.7291648	143/30	.6782147	127/30	.6266824	132/35	.5765059
147/18	.9120448	146/21	.8421336	128/21	.7849907	150/28	.7289333	138/29	.6774811	148/35	.6261937	143/38	.5755524
130/16	.9098234	139/20	.8419848	134/22	.7846821	123/23	.7281773	133/28	.6766936	131/31	.6259096	124/33	.5749078
138/17	.9094302	132/19	.8418203	140/23	.7844002	139/26	.7280415	147/31	.6759556	135/32	.6251838	139/37	.5748131
146/18	.9090804	125/18	.8416375	146/24	.7841417	149/28	.7260283	128/27	.6758462	139/33	.6245009	146/39	.5732883
129/16	.9064697	145/21	.8391487	121/20	.7817554	133/25	.7259116	142/30	.6751670	122/29	.6239618	131/35	.5732033
137/17	.9062717	138/20	.8388491	127/21	.7815844	138/26	.7249058	123/26	.6749318	143/34	.6238571	127/34	.5723248
145/18	.9060955	131/19	.8385177	133/22	.7814289	122/23	.7246320	137/29	.6743226	130/31	.6225817	138/37	.5716774
8/1	.9030900	124/18	.8381492	139/23	.7812870	143/27	.7239722	146/31	.6729912	138/33	.6213652	149/40	.5711263
143/18	.9000635	144/21	.8361432	145/24	.7811568	127/24	.7235925	127/27	.6724399	121/29	.6203874	145/39	.5703034
135/17	.8998849	137/20	.8356906	6/1	.7781513	132/25	.7226339	122/26	.6713865	146/35	.6202849	141/38	.5694355
127/16	.8996837	130/19	.8351898	149/25	.7752463	137/26	.7217473	136/29	.6711400	129/31	.6192280	137/37	.5685189
150/19	.8973377	123/18	.8346326	143/24	.7751248	121/23	.7210576	131/28	.6701133	133/32	.6187016	122/33	.5678459
142/18	.8970158	150/22	.8336686	137/23	.7749928	142/27	.7209245	145/31	.6700063	137/33	.6182067	133/36	.5675491
134/17	.8966559	136/20	.8325089	131/22	.7748486	131/25	.7193313	135/29	.6679358	141/34	.6177402	129/35	.5665217
126/16	.8962505	129/19	.8318361	125/21	.7746907	136/26	.7185656	121/26	.6678121	149/36	.6168838	125/34	.5654311
149/19	.8944327	122/18	.8310873	148/25	.7723217	146/28	.7171949	144/31	.6670008	124/30	.6163004	136/37	.5653372
141/18	.8939466	149/22	.8307636	142/24	.7720771	125/24	.7166988	130/28	.6667854	128/31	.6158483	147/40	.5652573
133/17	.8934027	142/21	.8300690	136/23	.7718111	130/25	.7160034	139/30	.6658935	136/33	.6150250	150/41	.5633074
125/16	.8927900	128/19	.8284564	130/22	.7715207	135/26	.7153605	125/27	.6655462	144/35	.6142945	139/38	.5632312
148/19	.8915081	148/22	.8278390	124/21	.7712024	140/27	.7147642	134/29	.6647068	127/31	.6124420	128/35	.5631420
140/18	.8908555	121/18	.8275129	147/25	.7693773	145/28	.7142100	143/31	.6639743	131/32	.6121213	135/37	.5621321
132/17	.8901250	141/21	.8269998	135/23	.7686060	150/29	.7136933	129/28	.6634317	139/34	.6115359	142/39	.5612237
124/16	.8893017	134/20	.8260748	129/22	.7681670	129/25	.7126497	147/32	.6621673	143/35	.6112680	131/36	.5609688
147/19	.8885637	127/19	.8250501	123/21	.7676858	134/26	.7121315	124/27	.6620579	122/30	.6092385	149/41	.5604024
139/18	.8877423	147/22	.8245946	146/25	.7664129	139/27	.7116510	133/29	.6614536	126/31	.6090088	149/42	.5599370
131/17	.8868224	133/20	.8228216	134/23	.7653770	149/29	.7107883	142/31	.6609266	134/33	.6085909	127/35	.5597357
123/16	.8857851	146/22	.8219302	128/22	.7647873	128/25	.7092700	137/30	.6595993	142/35	.6082203	134/37	.5589031
146/19	.8855993	126/19	.8216169	122/21	.7641405	133/26	.7088783	132/29	.6581759	150/37	.6078896	123/34	.5584262
138/18	.8846066	139/21	.8207955	139/24	.7628036	143/28	.7081780	141/31	.6578574	121/30	.6056641	148/41	.5574778
130/17	.8834945	132/20	.8195439	133/23	.7621238	148/29	.7078637	127/28	.6566457	125/31	.6055483	137/38	.5569370
145/19	.8826044	145/22	.8189453	127/22	.7613810	122/24	.7061486	136/30	.6564176	129/32	.6054397	133/37	.5556498
122/16	.8822398	125/19	.8181564	150/26	.7611180	127/25	.7058637	145/32	.6562180	133/33	.6053377	140/39	.5550634
137/18	.8814481	138/21	.8176598	121/21	.7605661	132/26	.7056006	122/27	.6549960	137/34	.6052417	147/41	.5545334
129/17	.8801408	131/20	.8162413	144/25	.7604225	137/27	.7053568	131/29	.6548733	141/35	.6051511	143/40	.5532760
144/19	.8796089	144/22	.8159398	132/23	.7588461	142/28	.7051303	140/31	.6547663	145/36	.6050555	132/37	.5523722
121/16	.8786654	124/19	.8146681	149/26	.7582130	147/29	.7049193	149/33	.6546724	149/37	.6049846	139/39	.5519502
136/18	.8782664	137/21	.8145013	126/22	.7579478	121/24	.7025742	148/33	.6517478	147/37	.5991156	146/41	.5515690
128/17	.8767611	150/23	.8143635	143/25	.7573940	126/25	.7024305	139/31	.6516531	4/1	.6020600	121/34	.5513055
143/19	.8765824	123/19	.8111515	137/24	.7565094	131/26	.7022980	130/39	.6515454	143/36	.5990335	135/38	.5505502
142/19	.8735347	149/23	.8114585	131/23	.7555435	136/27	.7021751	121/27	.6514216	139/35	.5989468	124/35	.5493537

GEAR LOGS .5490696 TO .2828051

Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log
131/37	.5490696	136/43	.5000704	134/47	.4550069	135/52	.4143305	143/60	.3771847	141/64	.3430391	127/62	.3114120
145/41	.5485841	139/44	.4995621	131/46	.4545135	122/47	.4142619	131/55	.3769086	145/66	.3418241	131/64	.3110913
127/36	.5475012	142/45	.4990758	128/45	.4539975	127/49	.4136076	126/53	.3760946	134/61	.3417750	133/65	.3109382
141/40	.5471591	145/46	.4986102	145/51	.4537978	145/56	.4131800	145/61	.3760382	123/56	.3417171	139/68	.3105059
123/35	.5458371	148/47	.4981738	125/44	.4534573	137/53	.4124447	140/59	.3752760	147/67	.3412425	143/70	.3102380
130/37	.5457417	129/41	.4978058	122/43	.4528913	142/55	.4119256	121/51	.3752152	125/57	.3410351	145/71	.3101097
137/39	.5456560	135/44	.4868811	139/49	.4528187	129/50	.4116197	147/62	.3749256	149/68	.3406774	149/73	.3098634
144/41	.5455786	135/43	.4968653	150/53	.4518154	121/47	.4106375	149/63	.3738458	127/58	.3403757	137/67	.3096458
150/43	.5426228	122/39	.4952952	133/47	.4517537	139/54	.4106210	137/58	.3732926	129/59	.3397377	124/61	.3080919
143/41	.5425521	147/47	.4952194	147/52	.4513140	149/58	.4097583	144/61	.3730327	142/65	.3393749	128/63	.3078695
136/39	.5424743	128/41	.4944261	127/45	.4505912	131/51	.4097011	125/53	.3726341	131/60	.3391200	132/65	.3076605
129/37	.5423880	131/42	.4940220	141/50	.4502491	136/53	.4092630	139/59	.3721628	133/61	.3385218	136/67	.3074641
122/35	.5422918	134/43	.4936363	138/49	.4496830	141/55	.4088564	127/54	.3714099	146/67	.3382781	140/69	.3072789
139/40	.5409548	137/44	.4932679	121/43	.4493169	146/57	.4084780	134/57	.3712299	135/62	.3379421	144/71	.3071042
125/36	.5406075	143/46	.4925782	149/53	.4489104	133/52	.4078483	148/63	.3709212	124/57	.3375468	148/73	.3069388
149/43	.5397178	146/47	.4922550	132/47	.4484760	143/56	.4071480	129/55	.3702270	137/63	.3373801	121/60	.3046341
142/41	.5395044	149/48	.4919451	129/46	.4478319	125/49	.4067139	143/61	.3700062	139/64	.3368348	123/59	.3045753
128/37	.5390083	121/39	.4917208	143/51	.4477658	130/51	.4063732	124/53	.3691458	128/59	.3363580	125/62	.3045183
121/35	.5387174	127/41	.4910198	137/49	.4465345	135/53	.4060579	131/56	.3690833	141/65	.3363057	127/63	.3044632
145/42	.5381187	133/43	.4903831	123/44	.4464524	145/57	.4054931	138/59	.3690271	143/66	.3358921	129/64	.3044097
131/38	.5374877	139/45	.4898023	148/53	.4459858	150/59	.4052393	145/62	.3689763	145/67	.3352932	131/65	.3043579
148/43	.5367932	145/47	.4892701	145/52	.4453647	127/50	.4048337	149/64	.3670063	132/61	.3352441	133/66	.3043077
141/41	.5364352	123/40	.4878451	131/47	.4451734	137/54	.4043268	142/61	.3669585	147/68	.3348084	135/67	.3042590
134/39	.5360402	126/41	.4875866	142/51	.4447181	147/58	.4038893	135/58	.3669058	121/56	.3345974	137/68	.3042117
127/37	.5356020	132/43	.4871054	139/50	.4440448	124/49	.4032256	128/55	.3668473	149/69	.3343372	139/69	.3041657
137/40	.5346606	141/46	.4864613	136/49	.4433428	134/53	.4028289	121/52	.3667821	136/63	.3341984	141/70	.3041211
147/43	.5338488	144/47	.4862646	147/53	.4430414	139/55	.4026521	137/59	.3658686	125/58	.3334820	143/71	.3040777
140/41	.5333341	150/49	.4858952	133/48	.4426114	149/59	.4023343	123/53	.3656392	127/59	.3329517	145/72	.3040355
133/39	.5327870	125/41	.4841261	130/47	.4418455	121/48	.4015442	146/63	.3650124	144/67	.3322877	147/73	.3039944
126/37	.5321688	131/43	.4838028	127/46	.4410459	131/52	.4012680	139/60	.3648635	131/61	.3319415	149/74	.3039546
143/42	.5320867	137/45	.4835081	149/54	.4407925	141/56	.4010311	125/54	.3645162	133/62	.3314599	2/1	.3010300
146/43	.5308844	143/47	.4832381	124/45	.4402092	123/49	.3997090	141/61	.3638893	148/69	.3314126	139/70	.2989168
129/38	.5308061	149/49	.4829902	135/49	.4401377	128/51	.3996398	127/55	.3634410	137/64	.3305406	149/75	.2981250
139/41	.5302309	121/40	.4807254	146/53	.4400770	133/53	.3995757	143/62	.3629443	122/57	.3304849	147/74	.2980856
149/44	.5297336	124/41	.4806378	140/51	.4385578	138/55	.3995164	136/59	.3626869	139/65	.3301014	145/73	.2980451
125/37	.5287083	127/42	.4805544	129/47	.4384918	143/57	.3994611	129/56	.3624017	126/59	.3295185	143/72	.2980035
145/43	.5278995	130/43	.4804749	137/50	.4377506	148/59	.3994097	122/53	.3620839	143/67	.3292612	141/71	.2979608
138/41	.5270952	133/44	.4803989	145/53	.4370921	147/59	.3964653	145/63	.3620275	145/68	.3288591	137/69	.2978715
121/36	.5264829	136/45	.4803264	134/49	.4369087	142/57	.3964134	131/57	.3613964	130/61	.3286136	135/68	.2978249
131/39	.5262067	139/46	.4802570	131/48	.4360301	137/55	.3963579	147/64	.3611373	149/70	.3280883	133/67	.2977768
124/37	.5252200	142/47	.4801904	139/51	.4354446	132/53	.3962980	140/61	.3607982	134/63	.3277643	131/66	.2977274
144/43	.5248940	145/48	.4801268	128/47	.4351121	127/51	.3962335	133/58	.3604236	138/65	.3269657	129/65	.2976763
127/38	.5240201	148/49	.4800656	125/46	.4341522	122/49	.3961627	149/65	.3602729	121/57	.3269105	127/64	.2976237
137/41	.5239367	3/1	.4771212	144/53	.4340866	149/60	.3950350	126/55	.3600078	123/58	.3264771	125/63	.2975695
147/44	.5238646	149/50	.4742163	141/52	.4332158	139/56	.3948268	135/59	.3594818	142/67	.3262135	123/62	.2975134
143/43	.5218675	146/49	.4741568	122/45	.4331473	129/52	.3945864	137/60	.3585693	125/59	.3260580	121/61	.2974556
133/40	.5217916	143/48	.4740948	149/55	.4328236	146/59	.3935009	121/53	.3585095	127/60	.3256524	148/75	.2952004
123/37	.5217034	140/47	.4740301	127/47	.4317058	136/55	.3931762	130/57	.3580685	146/69	.3255038	144/73	.2950396
136/41	.5207550	137/46	.4739628	143/53	.4310601	131/53	.3929954	139/61	.3576850	129/61	.3252599	140/71	.2948697
149/45	.5199738	134/45	.4738923	132/49	.4303778	121/49	.3925893	148/65	.3573483	131/62	.3248796	136/69	.2946898
139/42	.5197655	131/44	.4738186	148/55	.4298990	143/58	.3919180	141/62	.3568274	150/71	.3248330	132/67	.2944991
142/43	.5188198	128/43	.4737415	121/45	.4295729	133/54	.3914578	134/59	.3562528	135/64	.3241538	128/65	.2942966
122/37	.5181581	125/42	.4736607	137/51	.4291504	123/50	.3909351	143/63	.3559955	137/65	.3238072	124/63	.2940812
145/44	.5179153	122/41	.4735759	145/54	.4289742	150/61	.3907615	127/56	.3556157	139/66	.3234709	149/76	.2923727
135/41	.5175499	145/49	.4711719	126/47	.4282726	145/59	.3905160	145/64	.3551880	141/67	.3231443	145/74	.2921363
125/38	.5171264	139/47	.4709169	142/53	.4280124	140/57	.3902531	138/61	.3545493	143/68	.3228271	143/73	.2920131
148/45	.5170492	133/45	.4706391	123/46	.4271473	130/53	.3896675	147/65	.3544039	124/59	.3225697	139/71	.2917565
128/39	.5161454	127/43	.4703352	131/49	.4270752	125/51	.3893398	131/58	.3538433	145/69	.3225189	137/70	.2916226
141/43	.5157506	121/41	.4700015	139/52	.4270115	137/56	.3885326	149/66	.3536424	149/71	.3219280	133/68	.2913427
131/40	.5152113	147/50	.4683473	147/55	.4269546	149/61	.3878565	124/55	.3530590	128/61	.3218802	131/67	.2911965
121/37	.5145837	144/49	.4681664	136/51	.4259687	127/52	.3878004	133/59	.3529956	136/65	.3206255	127/65	.2908903
134/41	.5143209	138/47	.4677812	149/56	.4249983	144/59	.3875105	142/63	.3529478	140/67	.3200532	125/64	.2907300
137/42	.5134813	135/46	.4675760	141/53	.4249432	139/57	.3871399	146/65	.3514395	121/58	.3193574	121/62	.2903937
127/39	.5127391	129/44	.4671370	133/50	.4248816	134/55	.3867421	137/61	.3513908	123/59	.3190531	150/77	.2896006
140/43	.5126595	126/43	.4669020	125/47	.4248121	129/53	.3863138	128/57	.3513351	148/71	.3190034	146/75	.2892916
146/45	.5111404	149/51	.4656161	146/55	.4239902	124/51	.3858515	139/62	.3506231	127/61	.3184739	142/73	.2889654
133/41	.5110677	143/49	.4651399	130/49	.4237473	141/58	.3857911	121/54	.3503916	129/62	.3181980	138/71	.2886208
149/46	.5104285	137/47	.4646227	143/54	.4229422	148/61	.3849319	150/67	.3500165	131/63	.3179308	134/69	.2882557
123/38	.5102215	131/45	.4640588	127/48	.4225625	131/54	.3848775	132/59	.3497219	133/64	.3176716	130/67	.2878686
139/43	.5095463	125/43	.4634415	140/53	.4218521	143/59	.3844840	123/55	.3495424	137/66	.3171767	126/65	.2874571
129/40	.5085297	148/51	.4626915	124/47	.4213238	121/50	.3838154	143/64	.3491560	139/67	.3169400	122/63	.2870193
132/41	.5077900	142/49	.4620922	137/52	.4207173	133/55	.3834889	125/56	.3487220	141/68	.3167102	149/77	.2866956
138/43	.5064106	139/48	.4617736	129/49	.4203936	128/53	.3829341	136/61	.3482091	143/69	.3164869	147/76	.2865037
125/39	.5058454	136/47	.4614410	121/46	.4200276	135/56	.3821458	127/57	.3479288	147/71	.3160590	143/74	.2861043
141/44	.5057664	133/46	.4610938	134/51	.4195346	147/61	.3819875	129/58	.3471617	149/72	.3158538	141/73	.2858962
147/46	.5045595	127/44	.4603510	139/53	.4187389	142/59	.3814363	149/67	.3471115	122/59	.3155078	139/72	.2856823
131/41	.5044874	124/43	.4599532	131/50	.4153013	125/52	.3808067	131/59	.3464293	126/61	.3150407	137/71	.2854623
150/47	.5039934	121/42	.4595361	144/55	.4179998	137/57	.3808457	122/55	.3459971	130/63	.3146029	133/69	.2850025
137/43	.5032521	141/49	.4590230	123/47	.4178072	149/62	.3807946	133/60	.3457003	134/65	.3141914	131/68	.2847624
121/38	.5030018	135/47	.4582359	149/57	.4173114	139/58	.3795868	144/65	.3454491	138/67	.3138043	129/67	.2845149
124/39	.5023571	149/52	.4571830	128/49	.4170139	127/53	.3795278	135/61	.3450040	142/69	.3134392	127/66	.2842598
143/45	.5021235	146/51	.4567827	133/51	.4162814	146/61	.3790231	137/62	.3443289	146/71	.3130946	148/77	.2837710
127/40	.5017437	123/43	.4564366	125/48	.4156688	122/51	.3787896	148/67	.3441869	150/73	.3127684	123/64	.2837251
130/41	.5011595	143/50	.4563660	138/53	.4156032	141/59	.3783671	139/63	.3436743	121/59	.3119334	121/63	.2834449
149/47	.5010884	137/48	.4554794	148/57	.4143868	136/57	.3776640	130/59	.3430914	125/61	.3115802	140/73	.2828051

GEAR LOGS .2822806 TO .1174966

Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log
136/71	.2822806	124/69	.2545726	127/75	.2287424	147/92	.2035295	144/95	.1806389	141/98	.1579930	136/99	.1379037
128/67	.2811352	149/83	.2541082	149/88	.2287036	139/87	.2034955	147/97	.1805456	128/89	.1578200	125/91	.1378686
149/78	.2810917	131/73	.2539484	137/81	.2282356	131/82	.2034574	121/80	.1796954	148/103	.1574245	129/94	.1374618
145/76	.2805444	147/82	.2535034	125/74	.2276783	123/77	.2034144	127/84	.1795244	125/87	.1573907	133/97	.1370799
124/65	.2805083	138/77	.2533884	130/77	.2274527	142/89	.2028983	133/88	.1793689	135/94	.1572059	122/89	.1369698
143/75	.2802747	145/81	.2528830	140/83	.2270499	126/79	.2027434	139/92	.1792270	145/101	.1570466	137/100	.1367206
141/74	.2799874	127/71	.2525453	145/86	.2268695	145/91	.2023266	122/81	.1778748	122/85	.1569409	141/103	.1363819
139/73	.2796919	143/80	.2522460	150/89	.2267013	137/86	.2022221	125/83	.1778319	142/99	.1566531	145/106	.1360621
137/72	.2793881	134/75	.2520435	123/73	.2265822	121/76	.2019718	128/85	.1777911	139/97	.1562431	149/109	.1357598
135/71	.2790755	141/79	.2515920	133/79	.2262245	148/93	.2017788	131/87	.1777520	149/104	.1561530	138/101	.1355577
150/79	.2784642	148/83	.2511836	143/85	.2259171	132/83	.2014958	134/89	.1777148	136/95	.1558153	127/93	.1353208
131/69	.2784222	139/78	.2509202	121/72	.2254529	143/90	.2010935	137/91	.1776792	123/86	.1554066	131/96	.1350001
129/68	.2780808	130/73	.2506205	131/78	.2251767	127/80	.2007137	140/93	.1776451	133/93	.1553687	146/107	.1349691
146/77	.2778622	121/68	.2502765	136/81	.2250539	149/94	.2000584	143/95	.1776124	143/100	.1553360	139/102	.1344146
127/67	.2777289	137/77	.2502299	146/87	.2248336	122/77	.1998691	149/99	.1775511	130/91	.1549020	124/91	.1343803
125/66	.2773661	135/76	.2495202	129/77	.2240990	141/89	.1998291	146/97	.1775812	147/103	.1544801	143/105	.1341467
142/75	.2772270	126/71	.2491122	139/83	.2239367	144/91	.1993211	148/99	.1746265	137/96	.1544494	132/97	.1338022
123/65	.2769917	149/84	.2489070	149/89	.2237963	125/79	.1992829	145/97	.1745963	127/89	.1544137	121/89	.1333954
121/64	.2766054	133/75	.2487903	122/73	.2230369	128/81	.1987250	142/95	.1745647	144/101	.1540411	140/103	.1332908
138/73	.2765562	140/79	.2485009	127/76	.2229901	139/88	.1985321	139/93	.1745319	124/87	.1539024	125/92	.1331222
134/71	.2758465	147/83	.2482392	132/79	.2229468	131/83	.1981932	136/91	.1744975	131/92	.1534835	129/95	.1328661
149/79	.2755592	131/74	.2480396	137/82	.2229067	134/85	.1976859	133/89	.1744616	121/85	.1533665	148/109	.1328352
130/69	.2750943	145/82	.2475541	142/85	.2228694	145/92	.1975802	130/87	.1744241	138/97	.1531074	137/101	.1323992
145/77	.2748773	122/69	.2475107	147/88	.2228346	137/87	.1972013	127/85	.1743848	145/102	.1527678	141/104	.1321858
143/76	.2745224	129/73	.2472668	148/89	.2206717	129/82	.1967758	124/83	.1743436	125/88	.1524273	145/107	.1319842
126/67	.2742957	136/77	.2470482	143/86	.2208375	140/89	.1967380	121/81	.1743004	149/105	.1519970	149/110	.1317936
139/74	.2737831	143/81	.2468510	138/83	.2208010	121/77	.1962947	149/100	.1731863	139/98	.1517887	134/99	.1314796
122/65	.2734464	127/72	.2464712	133/80	.2207616	146/93	.1958700	143/96	.1730648	129/91	.1515483	142/105	.1310990
137/73	.2733977	141/80	.2461291	128/77	.2207193	135/86	.1958353	137/92	.1729328	146/103	.1515157	123/91	.1308637
148/79	.2726346	125/71	.2456517	123/74	.2206734	124/79	.1957946	131/88	.172[illegible]886	143/101	.1510146	127/94	.1306758
133/71	.2725933	139/79	.2453877	141/85	.2198002	149/95	.1954627	125/84	.1726307	126/89	.1509805	131/97	.1304996
131/70	.2721733	146/83	.2452748	131/79	.2196442	127/81	.1953187	150/101	.1717799	133/94	.1507237	139/103	.1301776
144/77	.2718718	123/70	.2448071	121/73	.2194625	130/83	.1948653	144/97	.1715908	140/99	.1504928	143/106	.1300301
127/68	.2712948	137/78	.2446260	149/90	.2189438	133/85	.1944327	141/95	.1714955	147/104	.1502840	147/109	.1298908
125/67	.2708352	121/69	.2439363	139/84	.2187355	147/94	.1941894	135/91	.1712924	137/97	.1499489	128/95	.1294864
136/73	.2702160	128/73	.2438871	134/81	.2186198	136/87	.1940196	132/89	.1711839	127/90	.1495612	136/101	.1292175
149/80	.2700963	135/77	.2438431	124/75	.2183604	139/89	.1936248	126/85	.1709516	134/95	.1493812	144/107	.1289787
121/65	.2698720	142/81	.2438033	147/89	.2179273	142/91	.1932469	123/83	.1708270	141/100	.1492191	121/90	.1285429
147/79	.2696902	149/85	.2437674	137/83	.2176425	131/84	.1929920	145/98	.1701419	148/105	.1490724	125/93	.1284271
132/71	.2693156	145/83	.2422899	127/77	.2173130	145/93	.1928851	139/94	.1698869	131/93	.1487884	133/99	.1282164
145/78	.2692734	138/79	.2422520	150/91	.2170499	148/95	.1925381	133/90	.1696091	145/103	.1485308	137/102	.1281204
141/76	.2684055	131/75	.2422100	145/88	.2168853	123/79	.1922780	127/86	.1693052	121/86	.1482869	145/108	.1279442
128/69	.2683609	124/71	.2421634	135/82	.2165199	137/88	.1922379	121/82	.1689715	128/91	.1481686	149/111	.1278633
139/75	.2679535	143/82	.2415221	130/79	.2163163	143/92	.1915482	149/101	.1688649	142/101	.1479669	122/91	.1273184
137/74	.2674889	129/74	.2413580	125/76	.2160964	129/83	.1915116	146/99	.1687177	149/106	.1478804	130/97	.1271717
124/67	.2673469	148/85	.2408428	143/87	.2158167	132/85	.1911550	143/97	.1685643	125/89	.1475200	138/103	.1270419
135/73	.2670109	134/77	.2406141	133/81	.2153666	149/96	.1909151	137/93	.1682377	139/99	.1473796	146/109	.1269264
146/79	.2667258	127/73	.2404808	146/89	.2149629	121/78	.1906908	134/91	.1680634	122/87	.1468405	123/92	.1261173
133/72	.2665191	139/80	.2399248	141/86	.2147206	138/89	.1904891	131/89	.1678813	129/92	.1468019	127/95	.1260801
131/71	.2660130	125/72	.2395775	136/83	.2144608	141/91	.1901777	128/87	.1676907	136/97	.1467672	131/98	.1260452
142/77	.2657976	144/83	.2392844	131/80	.2141813	127/82	.1899898	147/100	.1673173	143/102	.1467358	135/101	.1260124
129/70	.2654917	137/79	.2390035	149/91	.2141449	147/95	.1895937	122/83	.1672817	150/107	.1467075	139/104	.1259815
127/69	.2649546	149/86	.2386878	139/85	.2135959	133/86	.1893531	135/92	.1665460	144/103	.1455253	143/107	.1259522
149/81	.2647013	123/71	.2386478	121/74	.2135537	150/97	.1893196	129/88	.1661070	137/98	.1454945	147/110	.1259246
125/68	.2644011	147/85	.2378984	129/79	.2129626	139/90	.1887723	148/101	.1659403	130/93	.1454605	149/112	.1239683
147/80	.2642273	121/70	.2376874	142/87	.2127690	122/79	.1887327	145/99	.1657328	123/88	.1454224	145/109	.1239415
123/67	.2638303	140/81	.2376430	137/84	.2124413	125/81	.1884250	142/97	.1655166	141/101	.1448977	141/106	.1239133
134/73	.2637819	145/84	.2370887	145/89	.2119780	145/94	.1882401	139/95	.1652912	127/91	.1447623	137/103	.1238834
145/79	.2637409	126/73	.2370476	127/78	.2117091	128/83	.1881319	136/93	.1650560	145/104	.1443347	133/100	.1238516
141/77	.2627284	131/76	.2364577	122/75	.2112985	131/85	.1878524	149/102	.1645861	131/94	.1441434	129/97	.1238180
130/71	.2226851	143/83	.2362579	135/83	.2112557	134/87	.1875865	130/89	.1645534	124/89	.1440317	125/94	.1237821
139/76	.2622012	136/79	.2359118	148/91	.2112203	137/89	.1873306	127/87	.1642844	149/107	.1438025	121/91	.1237440
148/81	.2617767	141/82	.2354052	138/85	.2104602	143/93	.1868531	143/98	.1641099	135/97	.1435621	150/113	.1230129
137/75	.2616593	122/71	.2351015	125/77	.2104193	123/80	.1868151	124/85	.1640028	121/87	.1432661	142/107	.1229045
135/74	.2611021	146/85	.2349340	133/82	.2100377	146/95	.1866293	121/83	.1637073	146/105	.1431636	134/101	.1227834
144/79	.2607354	127/74	.2345720	128/79	.2095829	149/97	.1864146	137/94	.1635927	139/100	.1430148	126/95	.1226469
133/73	.2605267	139/81	.2345298	149/92	.2093985	135/88	.1858511	150/103	.1632541	132/95	.1428503	143/108	.1219122
122/67	.2602850	149/87	.2336670	123/76	.2090915	141/92	.1854313	131/90	.1630288	143/103	.1424988	139/105	.1218255
131/72	.2599388	137/80	.2336306	144/89	.2089725	121/79	.1851583	147/101	.1629959	147/106	.1420114	131/99	.1216361
149/82	.2593724	125/73	.2335871	131/81	.2087863	124/81	.1849367	141/97	.1624474	140/101	.1418066	127/96	.1215325
129/71	.2593314	142/83	.2332102	139/86	.2085163	127/83	.1847256	125/86	.1624115	133/96	.1415804	144/109	.1209260
127/70	.2587057	147/86	.2328188	134/83	.2080267	133/87	.1843323	138/95	.1621555	126/91	.1413291	136/103	.1207017
136/75	.2584776	135/79	.2327067	121/75	.2077241	136/89	.1841489	132/91	.1615325	137/99	.1410854	128/97	.1204383
125/69	.2580609	128/75	.2321487	129/80	.2074997	139/91	.1839734	129/89	.1611997	148/107	.1408779	149/113	.1201079
143/79	.2577089	133/78	.2317570	137/85	.2073017	142/93	.1838054	139/96	.1607436	123/89	.1405151	141/107	.1198353
123/68	.2573962	121/71	.2315271	124/77	.2069310	148/97	.1834900	123/85	.1604862	134/97	.1403331	137/104	.1196873
132/73	.2572510	143/84	.2310567	140/87	.2066087	125/82	.1830961	149/103	.1603491	127/92	.1400159	133/101	.1195302
150/83	.2570132	131/77	.2307806	127/79	.2061766	131/86	.1827728	133/92	.1600638	149/108	.1397625	129/98	.1193636
121/67	.2567106	148/87	.2307424	143/89	.2059460	137/90	.1824781	146/101	.1600315	131/95	.1395477	146/111	.1190299
139/77	.2565241	141/83	.2301410	130/81	.2054584	143/94	.1822081	140/97	.1593563	142/103	.1394511	121/92	.1189976
128/71	.2559517	124/73	.2300988	146/91	.2053105	149/98	.1819602	127/88	.1593210	135/98	.1391077	130/99	.1183082
137/76	.2559070	129/76	.2297761	125/78	.2048154	126/83	.1812924	137/95	.1589970	128/93	.1387271	143/109	.1179095
146/81	.2558679	134/79	.2294777	133/83	.2047735	129/85	.1811708	134/93	.1586219	139/101	.1386934	122/93	.1178769
142/79	.2546612	139/82	.2292009	141/88	.2047364	135/89	.1809438	121/84	.1585061	150/109	.1386648	139/106	.1177089
133/74	.2546199	144/85	.2289436	149/93	.2047034	138/91	.1806377	131/91	.1582299	147/107	.1379335	135/103	.1174966

Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log	Ratio	Log
131/100	.1172713	142/113	.0992099	124/103	.0805845	141/122	.0628593	148/133	.0464101	134/125	.0301948	146/141	.0151338
148/113	.1171833	123/98	.0986790	136/113	.0804605	149/129	.0625966	129/116	.0461317	149/139	.0301715	147/142	.0150290
127/97	.1170320	133/106	.0985457	148/123	.0803566	127/110	.0624110	139/125	.0461048	136/127	.0297352	148/143	.0149257
140/107	.1167442	143/114	.0984311	125/104	.0798767	142/123	.0623832	149/134	.0460815	121/113	.0296070	149/144	.0148238
149/114	.1162814	124/99	.0977865	131/109	.0798448	143/124	.0619143	141/127	.0454154	137/128	.0295106	121/117	.0145995
132/101	.1162525	129/103	.0977525	137/114	.0798157	128/111	.0618870	131/118	.0453893	123/115	.0292073	123/119	.0143581
145/111	.1160450	134/107	.0977210	143/119	.0797890	121/105	.0615961	121/109	.0453589	139/130	.0290714	125/121	.0141246
123/94	.1157772	139/111	.0976918	149/124	.0797646	144/125	.0614525	132/119	.0450269	125/117	.0287241	127/123	.0138986
124/95	.1156981	144/115	.0976647	145/121	.0785826	129/112	.0613717	143/129	.0447463	140/131	.0288567	129/125	.0136797
137/105	.1155313	149/119	.0976393	139/116	.0785568	137/119	.0611736	133/120	.0446704	142/133	.0284367	131/127	.0134676
133/102	.1152514	146/117	.0961670	133/111	.0785286	145/126	.0609975	134/121	.0443194	127/119	.0282567	133/129	.0132619
142/109	.1148618	141/113	.0961407	127/106	.0784978	130/113	.0608650	145/131	.0440967	143/134	.0282312	135/131	.0130625
125/96	.1146388	136/109	.0961124	121/101	.0784640	146/127	.0605492	135/122	.0439740	145/136	.0278291	137/133	.0128690
121/93	.1143025	131/105	.0960820	140/117	.0779421	123/107	.0605213	125/113	.0438316	129/121	.0278043	139/135	.0126810
134/103	.1142678	126/101	.0960491	128/107	.0778262	131/114	.0603664	136/123	.0436338	146/137	.0276323	141/137	.0124985
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127/98	.1125776	143/115	.0946382	149/125	.0762763	133/116	.0593936	140/127	.0423243	137/129	.0261409	122/119	.0108128
149/115	.1124885	133/107	.0944678	143/120	.0761548	149/130	.0592429	141/128	.0420091	121/114	.0258805	124/121	.0106363
136/105	.1123496	128/103	.0943728	137/115	.0760228	134/117	.0589189	131/119	.0417243	139/131	.0257435	125/122	.0105602
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133/103	.1110144	135/109	.0929073	121/102	.0741852	137/120	.0575394	123/112	.0406871	145/137	.0246474	136/133	.0096873
129/100	.1105897	125/101	.0925886	134/113	.0740264	129/113	.0575113	146/133	.0405013	127/120	.0246225	137/134	.0096158
138/107	.1104953	131/106	.0919654	147/124	.0738956	121/106	.0574795	124/113	.0403433	128/121	.0244246	139/136	.0094759
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143/111	.1100130	121/98	.0915593	122/103	.0735226	122/107	.0569760	125/114	.0400051	129/122	.0242299	142/139	.0092735
121/94	.1096575	137/111	.0913976	148/125	.0733517	139/122	.0566550	148/135	.0399279	130/123	.0240383	143/140	.0092080
130/101	.1096220	132/107	.0911901	129/109	.0731632	131/115	.0565735	137/125	.0398106	149/141	.0239672	145/142	.0090797
139/108	.1095910	127/103	.0909665	123/104	.0728718	140/123	.0562229	126/115	.0396727	131/124	.0238496	146/143	.0090169
148/115	.1095639	143/116	.0908780	136/115	.0728411	124/109	.0559952	149/136	.0396474	132/125	.0236639	148/145	.0088937
149/116	.1087283	122/99	.0907246	149/126	.0728158	149/131	.0559150	150/137	.0393707	133/126	.0234811	149/146	.0088334
140/109	.1087015	133/108	.0904278	150/127	.0722876	141/124	.0557974	127/116	.0393457	134/127	.0233011	121/119	.0072384
131/102	.1086701	149/121	.0904009	131/116	.0722626	133/117	.0556657	139/127	.0392111	135/128	.0231238	123/121	.0071197
122/95	.1086362	139/113	.0899364	124/105	.0722324	142/125	.0553783	128/117	.0390241	136/129	.0229492	125/123	.0070049
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132/103	.1077367	124/101	.0891003	139/118	.0711328	144/127	.0545588	143/131	.0380647	141/134	.0221143	133/131	.0065803
137/107	.1073368	146/119	.0888059	126/107	.0709867	145/128	.0541580	145/133	.0375164	121/115	.0220876	135/133	.0064822
142/111	.1069653	141/115	.0885213	133/113	.0707732	128/113	.0541316	133/122	.0374918	142/135	.0219545	137/135	.0063868
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124/97	.1066500	125/102	.0882098	127/108	.0703799	146/129	.0537632	134/123	.0371997	144/137	.0216419	141/139	.0062043
147/115	.1066195	131/107	.0878875	121/103	.0699482	121/107	.0534016	135/124	.0369121	145/138	.0214889	143/141	.0061169
129/101	.1062683	126/103	.0875333	128/109	.0697835	147/130	.0533739	123/113	.0368267	125/119	.0213630	145/143	.0060320
143/112	.1061180	137/112	.0875026	142/121	.0695029	139/123	.0531097	136/125	.0366289	146/139	.0213381	147/145	.0059493
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121/95	.1050618	133/109	.0864251	137/117	.0685347	141/125	.0523091	127/117	.0356178	131/125	.0203613	124/123	.0035166
135/106	.1050279	139/114	.0861099	131/112	.0680533	150/133	.0522397	140/129	.0355383	133/127	.0200479	125/124	.0034883
149/117	.1050004	128/105	.0860207	145/124	.0679463	133/118	.0519696	141/130	.0352757	137/131	.0194493	126/125	.0034605
145/114	.1044631	145/119	.0858210	125/107	.0675262	125/111	.0515870	129/119	.0350427	139/133	.0191632	127/126	.0034332
131/103	.1044341	123/101	.0855837	132/113	.0674955	134/119	.0515578	142/131	.0350170	143/137	.0186154	128/127	.0034063
136/107	.1041551	129/106	.0852838	139/119	.0674678	143/127	.0515323	144/133	.0345109	145/139	.0183532	129/128	.0033797
127/100	.1038037	141/116	.0847611	148/127	.0674580	145/129	.0507783	131/121	.0344859	121/116	.0183274	130/129	.0033537
146/115	.1036551	133/112	.0846336	146/125	.0674429	136/121	.0507535	145/134	.0342632	122/117	.0181739	131/130	.0033279
137/108	.1032968	130/107	.0845596	141/121	.0664337	127/113	.0507253	146/135	.0340191	123/118	.0180231	132/131	.0033026
123/97	.1031334	147/121	.0845319	134/115	.0664070	137/122	.0503608	133/123	.0339465	124/119	.0178747	133/132	.0032777
128/101	.1028886	142/117	.0841024	127/109	.0663772	147/131	.0500460	147/136	.0337784	149/143	.0178503	134/133	.0032532
147/116	.1028593	125/103	.0840728	149/128	.0659763	129/115	.0498919	121/112	.0335674	126/121	.0175851	135/134	.0032290
138/109	.1024526	131/108	.0838475	135/116	.0658758	139/124	.0495931	148/137	.0335411	127/122	.0174439	136/135	.0032051
143/113	.1022576	137/113	.0836422	121/104	.0657521	121/108	.0493616	149/138	.0333072	128/123	.0173049	137/136	.0031817
148/117	.1020758	143/118	.0834540	143/123	.0654309	149/133	.0493347	122/113	.0332814	129/124	.0171680	138/137	.0031585
139/110	.1016221	149/123	.0832812	136/117	.0653530	131/117	.0490854	150/139	.0330765	131/126	.0169008	139/138	.0031357
149/118	.1013043	132/109	.0831474	122/105	.0651705	122/109	.0489333	137/127	.0329169	132/127	.0167702	140/139	.0031132
125/99	.1012748	144/119	.0828155	137/118	.0648386	123/110	.0485124	124/115	.0327239	133/128	.0166416	141/140	.0030911
130/103	.1011062	121/100	.0827854	123/106	.0645992	142/127	.0484846	125/116	.0324520	134/129	.0165151	142/141	.0030692
135/107	.1009500	127/105	.0826144	138/119	.0643321	143/128	.0481260	139/129	.0324251	136/131	.0162676	143/142	.0030477
140/111	.1008050	133/110	.0824589	131/113	.0641929	124/111	.0480987	141/131	.0319478	137/132	.0161467	144/143	.0030265
150/119	.1005443	139/115	.0823170	124/107	.0640379	125/112	.0476920	127/118	.0319217	138/133	.0160275	145/144	.0030055
121/96	.1005142	122/101	.0820384	139/120	.0638356	135/121	.0475484	128/119	.0316630	139/134	.0159100	146/145	.0029849
131/104	.1002380	134/111	.0817818	147/127	.0635136	126/113	.0472921	143/133	.0314844	140/135	.0158942	147/146	.0029644
141/112	.1000011	146/121	.0815675	125/108	.0634862	146/131	.0470816	130/121	.0311580	141/136	.0156802	148/147	.0029444
122/97	.0995881	129/107	.0812059	140/121	.0633426	127/114	.0468988	131/122	.0309115	142/137	.0155677	149/148	.0029246
127/101	.0994823	135/112	.0811158	133/115	.0631538	137/123	.0468155	147/137	.0305967	143/138	.0154569	150/149	.0029050
137/109	.0992941	147/122	.0809575	126/109	.0629440	128/115	.0465122	133/124	.0304299	144/139	.0153477		

Electromagnetic Pumps

DESIGN ABSTRACTS

. . . circulate liquid metals without moving parts

By J. F. Cage Jr.
Knolls Atomic Power Laboratory
General Electric Co.
Schenectady, N. Y.

IN THE development of means for converting atomic power into more controllable and conventionally usable form, a large effort has been devoted to the utilization of liquid metals as heat transfer media. Because of certain requirements for liquid metal systems, the development has included the investigation of a number of unusual means of pumping. One such means—the electromagnetic pump — has proved to be uniquely suited to the circulation of certain of the liquid metals. Its success in this field may help open the door to a more widespread use of liquid metals as heat transfer fluids, and is therefore of general interest. The pumps themselves are of interest as unusual pieces of equipment, having no seals or stuffing boxes, and (at least in theory) no moving parts other than the fluid itself.

Several particular requirements caused the electromagnetic pump to be studied. First and foremost, pumps, to be usable in any radio-

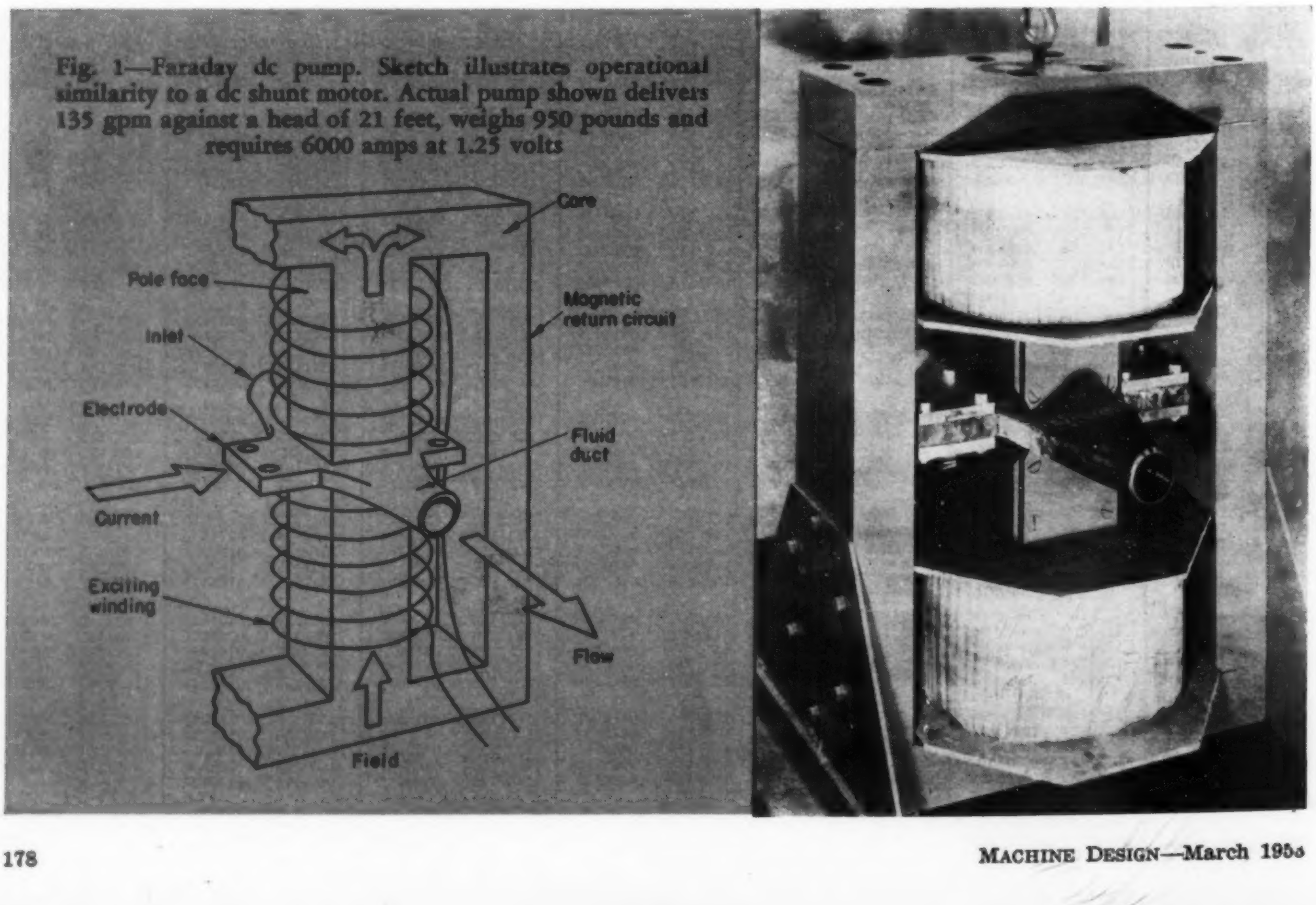


Fig. 1—Faraday dc pump. Sketch illustrates operational similarity to a dc shunt motor. Actual pump shown delivers 135 gpm against a head of 21 feet, weighs 950 pounds and requires 6000 amps at 1.25 volts

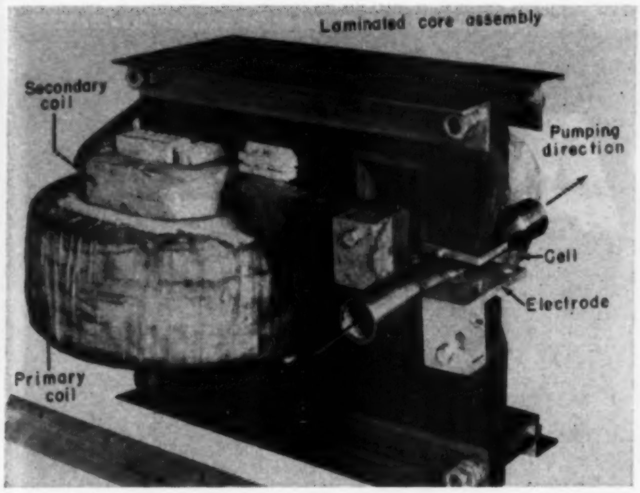


Fig. 2—Faraday ac pump. Modified from the dc type, *Fig.* 1, these pumps are hampered by low efficiency and bulky magnetic circuits which limit satisfactory applications to small sizes

Fig. 3—Helical flow induction pump. Capable of developing heads as high as 260 feet of sodium, these units are best suited for high-pressure, low-flow applications where space is at a premium

active liquid metal system, must be leakless—to a degree higher than that achieved with any known conventional shaft seal. Second, they must have a high degree of dependability such as might be obtained with a device having no moving parts to wear out. In addition, sodium and its potassium alloys (commonly called NaK) have been widely considered as suitable reactor coolants, and their properties make them unusually amenable to pumping by electromagnetic means. A number of different types of electromagnetic pumps have been studied and built as a part of the work in the field of liquid metals, both to supply the requirements of various heat transfer experiments using sodium and NaK, and to obtain design information for possible future application.

All electromagnetic pumps utilize the "motor" principle; that a conductor in a magnetic field, carrying a current which flows at right angles to the direction of the field, has a force exerted on it which is mutually perpendicular to both the field and the current. In all of these units the fluid is the conductor. The force, suitably directed in the fluid, manifests itself as a pressure if the fluid is properly contained. The field and the current can be produced in different ways and the force may be utilized in different ways. There are, therefore, a number of different types of electromagnetic pumps, all of them utilizing this principle.

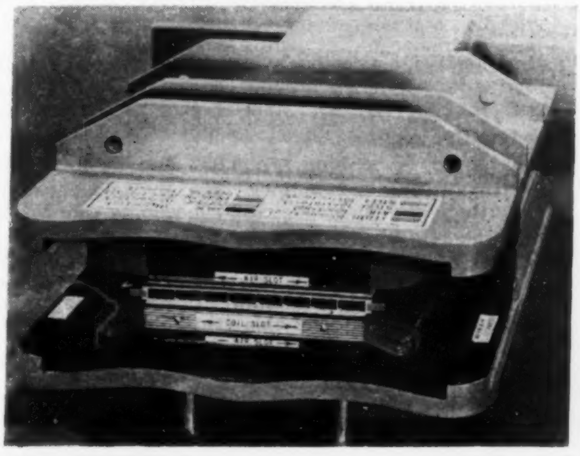
Faraday DC Pump: The most elementary electromagnetic pump has been called the Faraday type, *Fig*. 1. Liquid metal is contained in a thin-walled duct, usually of square or rectangular cross section. A constant magnetic field is passed through the fluid on one axis perpendicular to the direction of flow. The field is developed by a winding, dc excited, arranged on a suitable magnetic core, which provides both pole faces and a magnetic return path. Current is forced through the fluid by impressing a voltage across the axis of the duct mutually perpendicular to both the field and the direction of flow. Usually "electrodes" are attached directly to the walls of the duct by brazing. These elements are shown diagrammatically in the sketch in *Fig.* 1.

Operation is similar to a dc shunt motor. The separately excited field magnetizes the gap. Flow of the current in the fluid in the gap is similar to current in a dc motor armature. An I^2R loss appears in the fluid. As the fluid flows a "back voltage" or emf is generated by the fluid moving in the field, opposing the flow of current in the fluid. The product of this back voltage and the effective current in the fluid represents the pumping power developed.

Some current will flow through the walls and create a loss. In order to minimize this loss, the walls are kept as thin as possible, and are normally made of material with as high a resistivity as can be used. For sodium and NaK, stainless steel type 347, or the equivalent, and Inconel have been used without prohibitive losses. Current can also by-pass the magnetic field by flowing down the duct, across, and back to the electrode. This effect

(*Continued on page* 250)

Fig. 4—Linear induction pump. This type, a modification of the helical pump in *Fig.* 3, provides large flow at moderate heads for limited space and power supplies

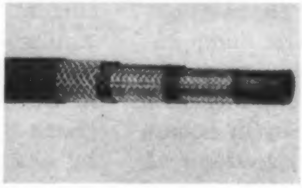


NEW PARTS
AND MATERIALS

. . . presented in quick-reference data sheet form for the convenience of the reader. For additional information on these new developments, see Page 199

STEAM HOSE 1
. . . reinforced with braided glass

Quaker Rubber Corp. Div., H. K. Porter Co. Inc., Tacony and Comly Sts., Philadelphia 24, Pa.



Glass cord braid provides heat insulation as well as strength.

Designation: Ironsides.

Size: ½ to 1¼ in. ID.

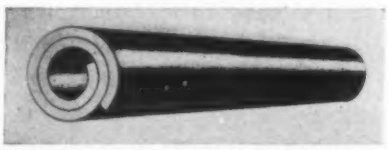
Service: Flexible and kinkproof; working pressures to 200 psi; resists high temperatures; has high burst resistance.

Design: Reinforced hose; tube and cover of heavy gage Ebonite; reinforced with inner wire braids and outer braid of glass cord.

For more data circle MD-1, Page 199

PIN FASTENERS 2
. . . now available in small sizes

C. E. M. Co., 24 School St., Danielson, Conn.



Smallest size previously available was $\frac{1}{16}$-in. diam; $\frac{1}{32}$-in. diam is now available.

Designation: Spirol.

Size: ⅛ to ⅜-in. long, $\frac{1}{32}$, 0.052 and $\frac{3}{64}$-in. diam.

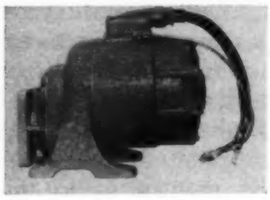
Service: Spring action locks pin in hole throughout length; easily inserted; resist loosening due to shock and vibration; resist corrosion.

Design: Type 302 non heat-treated or type 414 heat-treated stainless steel strip rolled into spiral coil; other sizes to ½-in. diam of brass, aluminum or other flexible material also available.

For more data circle MD-2, Page 199

HIGH-CYCLE GEARMOTOR 3
. . . light but powerful

U. S. Electric Motors Inc., Aircraft Div., Terminal Annex Box 2058, Los Angeles 54, Calif.



Developing 16 hp this motor weighs only 28 lb.

Designation: Syncrogear.

Size: 16 hp.

Service: Operates on 400 cycle, 3 phase ac; for intermittent duty; output speeds from 1500 to 5000 rpm.

Design: Meets AF Spec 32590; has hardened and shaved helical gears; internal spline take-off shaft; integral ventilating fan; AN mounting pad and pyramidal mounting base.

For more data circle MD-3, Page 199

PROTECTIVE COATING 4
. . . is flexible to —45 F

Munray Products Inc., 12400 Crossburn Ave., Cleveland 11, O.

This resilient rubber-like coating is highly abrasion resistant.

Designation: Cycoflex No. 7731.

Form: Liquid.

Service: Protecting metal parts from corrosion and abrasion; resists oils, greases, acids, alkalies, salts and petroleum solvents; applied by dipping and baking; coating can be applied from $\frac{1}{32}$ to ½ in. thick.

Properties: Dense, tough, resilient, rubber-like coating; color, black; specific gravity, 1.20 to 1.25; Shore A2 hardness, 65 to 70; tear resistance, 225 to 250 psi; passes Army Ordnance specifications for fungus resistance.

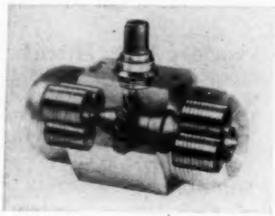
For more data circle MD-4, Page 199

NEW PARTS AND MATERIALS

FLOW ALARM SYSTEM 5

. . . gives alarm when flow rate is excessive

Potter Aeronautical Co., 87 Academy St., Newark, N. J.



Flow sensing element of this system operates at temperatures from −455 F to 1200 F.

Designation: Max-Alarm.

Size: Sensing elements $\frac{3}{16}$ to 6 in. diam.

Service: Operating controls or alarm system when rate of flow exceeds desired value; can be used with toxic or highly corrosive liquids, viscous fluids or liquefied gases; for flow rates from 0.2 to 4000 gpm and pressures to 20,000 psi; relay contacts rated 8 amp at 125 v; flow sensing unit unaffected by pressure variations.

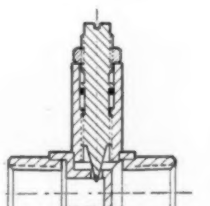
Design: Excessive flow alarm system; consists of flow sensing element, rectifier unit and relays; sensing unit generates ac proportional to flow rate which is rectified and applied to relays; signal light and reset button on panel; units for signaling low flow rate also available.

For more data circle MD-5, Page 199

NEEDLE VALVES 6

. . . accurately control fluid flow

Fluid Controls Inc., 1284 N. Center St., Mentor, O.



An ordinary wrench and screw driver are used to adjust this valve.

Designation and Size: 45000-2 has $\frac{1}{4}$-in. pipe size ports, weighs 5$\frac{3}{4}$ oz, is 2$\frac{1}{16}$ in. long, $\frac{7}{8}$-in. wide and 2$\frac{21}{32}$ in. high; 45000-3 has $\frac{3}{8}$-in. pipe size ports, weighs 6$\frac{3}{4}$ oz, is 2$\frac{1}{16}$ in. long, 1 in. wide and 2$\frac{25}{32}$ in. high; 45000-4 has $\frac{1}{2}$-in. pipe ports, weighs 9$\frac{3}{4}$ oz, is 2$\frac{1}{16}$ in. long, 1$\frac{1}{4}$ in. wide and 3$\frac{1}{32}$ in. high.

Service: Controlling fluid flow; easily adjusted; leakproof; long trouble-free life; burst pressures exceed 10,000 psi; 45000-2 has flow rating of 3 gpm at 200 psi when fully opened; 45000-3, 4.8 gpm approximately at 200 psi; 45000-4, 8.4 gpm approximately at 200 psi.

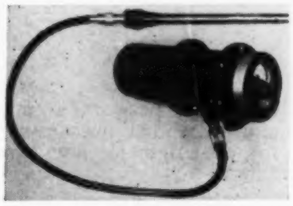
Design: Steel bodies, copper-brazed; O-ring seal used on stem; adjustment locknut loads stem in same direction as fluid pressure; stem has slot to permit adjustment with screw driver.

For more data circle MD-6, Page 199

LEVEL CONTROL 7

. . . controls within fraction of an inch

Greylor Co., 605 W. Washington Blvd., Chicago 6, Ill.



Completely sealed and gasketed unit is unaffected by humidity or temperature.

Designation: Ktrol.

Size: 3$\frac{3}{4}$ OD by 9$\frac{1}{2}$ in. long control housing; probe to meet requirements.

Service: Controlling level of material in tanks or vats; probes resist corrosion; may be used with nonconductive materials; operates from 110 v 60 cycle ac; may be used at high temperatures and pressures.

Design: Probe contains bridge network which becomes unbalanced due to change in dielectric when probe is immersed in liquid; unbalance of bridge network changes plate current of relaxation oscillator to operate a relay; relay may actuate valve, motor or alarm system; available in oil-filled housing for applications requiring explosionproof installation.

For more data circle MD-7, Page 199

FLEXIBLE CONDUIT 8

. . . for use in wet locations

American Brass Co., Waterbury 20, Conn.

Claimed to be the first of its kind to gain Underwriters' Laboratories approval for use in wet locations.

Designation: Sealtite Type UA.

Size: $\frac{3}{8}$ to 1$\frac{1}{4}$ in. ID.

Service: Protecting wiring against moisture, oil, dirt, chemicals and corrosive fumes in permanent or temporary installations; overcomes problems of movement, vibration and misalignment both indoors and outdoors; light and flexible for easy installation; can be cut to any length.

Design: Liquid-tight conduit; tough, extruded synthetic covering over flexible metal core; conduit is made of spirally wound, interlocked zinc-plated steel strip; on inside of conduit is a copper bonding conductor wound spirally in space between each convolution; Underwriters' approved fittings for use with conduit available.

For more data circle MD-8, Page 199

NEW PARTS AND MATERIALS

LOW PRESSURE CONTROLS 9

. . . for pressures from zero to 20 in. of water

Coral Designs Div., Henry G. Dietz Co., 12-16 Astoria Blvd., Long Island City 2, N. Y.

Silicone-impregnated glass-cloth diaphragms assure long life at high or low temperatures.

Designation: 101 P.

Size: 5⅞ in. high, 4½ in. wide and 4 in. long; ½-20 pressure connection; ½-in. conduit connection.

Service: Opening or closing electrical circuits to control air pressure; available for maximum pressures aluminum is waterproof.
of 0.2, 0.4, 0.8 and 2.0 in. of water, respectively; electrical rating of 10 amp at 125 v ac or 5 amp at 250 v ac.

Design: Single-pole, double-throw switch, actuated by diaphragm; housing of cast aluminum; external knob for setting operating point at any desired point in pressure range; available with static or impact pressure tube, if desired.

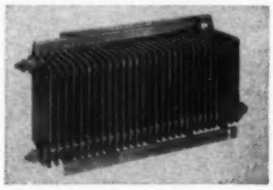
For more data circle MD-9, Page 199

SELENIUM RECTIFIER CELL 11

. . . rated at 36 volts RMS

Federal Telephone and Radio Corp., 100 Kingsland Rd., Clifton, N. J.

Provides high efficiency, compact design and light weight, particularly for 100 or more dc volts.



Designation: 300 series.

Size: Cell sizes, 1 in sq, $1\frac{3}{32}$ by $1\frac{13}{64}$ in., $1\frac{17}{32}$ in. sq, 2 in. sq, 2⅝ in. diam, $3\frac{5}{16}$ in. diam, $3\frac{3}{16}$ in. sq, 4⅜ in. diam, 4¼ by 6 in., 4½ by 6⅝ in., 5 by 6 in.

Service: Providing rectified dc; continuous current ratings for resistive and inductive loads with normal convecton cooling in 35 C ambient temperature are—single-phase half-wave 0.075 to 6 amp dc, single-phase bridge or center-tap 0.15 to 12 amp dc, three-phase half-wave 0.2 to 15.8 amp dc, three-phase bridge 0.225 to 18 amp dc, three-phase center-tap 0.27 to 22 amp dc.

Design: Selenium rectifier cell; painted yellow-gold.

Applications: Aircraft electrical equipment, servosystems, dc welders, battery chargers, power supplies, magnetic amplifiers and guided missiles.

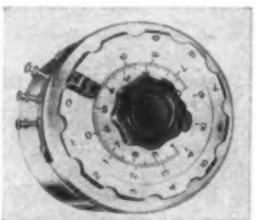
For more data circle MD-11, Page 199

DECADE POTENTIOMETERS 10

. . . have linearity closer than ±0.01 per cent

Brown Electro-Measurement Corp., 4635 S.E. Hawthorne Blvd., Portland 15, Ore.

Dial arrangement provides effective scale length of 390 in. which is approximately equivalent to that of a 100-turn helical potentiometer.



Designation: Dekapot DP-211.

Size: 3 in. diam, 7¼ in. overall length; extends 6 in. back of mounting panel; mounts on panel up to ¼-in. thick, has $\frac{3}{8}$-in. panel bushing.

Service: Varying electrical resistance; will dissipate 5 w; maximum resistance, 10,000 ohm; accuracy, ±0.05% or better; linearity, ±0.01% or better; resolution, 0.002%; very low variation with temperature or frequency; resistance value easily set and easily read; life of 500,000 cycles or more.

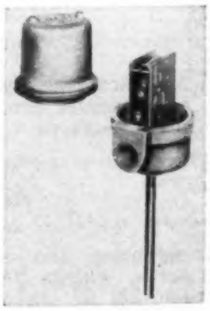
Design: Potentiometer made up of eleven 1000-ohm resistors, eleven 200-ohm resistors and one 400-ohm potentiometer; coaxial control knobs place readings on horizontal line; resistors noninductively wound of wire with low temperature coefficient of resistivity; also available in single-decade model and as rheostat.

For more data circle MD-10, Page 199

THERMAL SWITCH 12

. . . operates over wide temperature range

Burling Instrument Co., 5 Vose Ave., South Orange, N. J.



May be easily set to operate at any temperature between −300 and 300 F.

Designation: Model B-1C.

Size: Temperature sensitive tube, 5, 10 or 15 in. long, ⅜ or ½-in. OD; ½-in. IPS thread for wiring connection.

Service: Opening, closing, or opening and closing electrical circuits when set temperature is reached; switch contacts rated 15 amp at 125, 250, or 460 v 60 cycle ac; operating differential of ±½ F can be obtained.

Design: Thermal switch using differential expansion principle; expansion is multiplied by lever to actuate snap-action switch; adjusting screw, dial and lock screw for changing temperature settings; switch may be normally-open, normally-closed or single-pole double-throw; switch housing of cast aluminum is waterproof.

For more data circle MD-12, Page 199

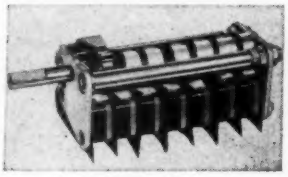
NEW PARTS AND MATERIALS

SWITCH ASSEMBLY 13

. . . small, lightweight control for 7 circuits

Micro Div., Minneapolis-Honeywell Regulator Co., Freeport, Ill.

Made up of seven single-pole, double-throw switches, this assembly is only 4¾ in. long.



Designation: 7AS71.

Size: 1½ by 1⅝ by 4¾.

Service: Opening or closing seven electric circuits simultaneously or in a desired sequence; individual switches rated 10 amp at 30 v dc inductive or heater load at sea level, 6 amp at 50,000 ft altitude; ac rating for inductive or heater load is 10 amp at 125 or 250 v; assembly has exceptional vibration resistance.

Design: Seven snap-action V-3 Micro switches and rotary actuator; eight detented switching positions at 45 degrees of rotation; switches actuated by cams and cam followers; other models using from 3 to 8 switches and from 2 to 8 switching positions are also available.

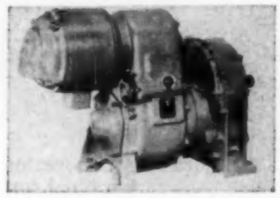
For more data circle MD-13, Page 199

DOUBLE REDUCTION DRIVES 15

. . . low-speed for heavy duty service

Sterling Electric Motors Inc., 5401 Anaheim-Telegraph Rd., Los Angeles 22, Calif.

Infinite speed variation at low output rpm is provided by these drives.



Designation: Type KFEB.

Size and Service: 20 hp size available with maximum output speeds from 176 to 42 rpm; 25 hp size has maximum speeds from 176 to 64 rpm; both available with speed variation of 2 to 1, 3 to 1 or 4 to 1; accurately maintain selected speed; for heavy-duty service.

Design: Double reduction variable-speed drives; variable speed transmission utilizes variable-pitch pulleys and V-belts; drip-proof, splash-proof and totally enclosed, fan-cooled models available; drip-proof and splash-proof models have straight-through cooling system; totally enclosed, fan cooled models have both internal and external cooling fans.

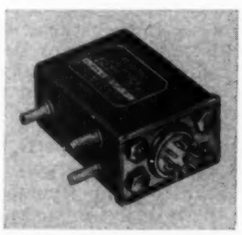
For more data circle MD-15, Page 199

HERMETICALLY SEALED RELAYS 14

. . . protected by dry nitrogen atmosphere

Automatic Electric Sales Corp., 1033 W. Van Buren St., Chicago 7, Ill.

These relays meet or exceed all provisions of MIL-R-6106 specification for relays.



Designation: RM 10 through 13.

Size: 2$\frac{1}{32}$ in. high, 1½ in. wide and $\frac{31}{32}$-in. thick; 6-32 mounting studs; weighs 1⅞ oz.

Service: Ambient temperature range, −55 to 75 C; withstand 10.5*g* min vibration and 10 to 55 cycles per second with maximum excursion of 0.060-in.; will withstand 25*g* shock; operating time range, 0.002 to 0.016-second; contacts, normally twin, will carry 135/w or 2 amps inductive or noninductive, will make or break 50/w or ½-amp inductive or 1 amp noninductive; RM 10, 11 have coil resistance of 500 ohm and operate on 24 v with minimum current of 0.0254-amp; RM 12, 13 have 5000 ohm coil resistance and operate on 48 v with minimum current of 0.008-amp.

Design: Metal-glass, solder-hook terminals; RM 10, 13 have mounting studs on bottom; RM 11, 12 have mounting studs on side; steel housings filled with dry nitrogen.

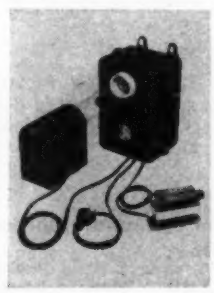
For more data circle MD-14, Page 199

PHOTOELECTRIC COUNTER 16

. . . packaged unit, easily installed

Photoswitch Inc., 77 Broadway, Cambridge 42, Mass.

Installed by mounting units in desired positions and plugging into 115 v ac outlet.



Designation: PIC.

Size: Light source is 2⅛ in. wide, 3¾ in. long and 3⅞ in. high; photocell and relay unit is 5⅞ in. wide, 8¼ in. high and 4½ in. deep; counter is 3$\frac{9}{16}$ in. long, 1⅜ in. wide and 2$\frac{9}{16}$ in. high.

Service: Counting to 600 counts per minute; operates on 115 v 60 cycle ac; relay rated 2 amp at 115 v ac, noninductive, will operate up to six counters; light beam must be completely broken and restored between counts for at least 1/20 second; maximum count 999,999.

Design: Counter set, consisting of light source, photoelectric cell and relay and electric counter; when light beam is broken by objects being counted, relay actuates electric counter; light source uses standard 15 cp automotive lamp; control unit uses 35L6 vacuum tube and 1P40 phototube.

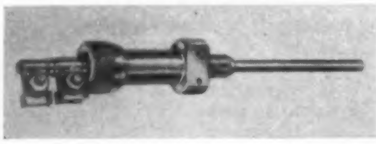
For more data circle MD-16, Page 199

NEW PARTS AND MATERIALS

THERMAL SWITCH 17

. . . will operate at 2000 F

Control Products Inc., 306 *Sussex St., Harrison, N. J.*



Temperature calibration within plus or minus 25 F has been maintained for 100 hr at 2000 F.

Designation: Type ASA-21-2.

Size: Maximum diam, 1⅛ in., 7¼ in. overall length; ½-20 NF-3 mounting threads; weighs 6 oz.

Service: Closing electrical circuit when preset temperature is reached; electrical contacts rated ¼ amp at 28 v resistive; normal temperature range from 60 to 1500 F; will operate at 2000 F for short periods, not harmed by temperatures as low as −70 F; maximum head temperature, 800 F.

Design: Thermal switch made of special stainless steel alloys; low expansion element is quartz rod; contacts are platinum iridium; may be had with ⅜ NPT mounting threads; has two wires for making electrical connections.

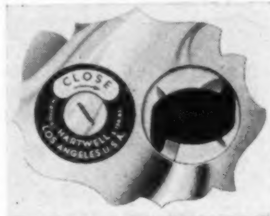
For more data circle MD-17, Page 199

FLUSH ACCESS DOOR 19

. . . opened by half turn with screwdriver

Hartwell Co., 9035 *Venice Blvd., Los Angeles* 34, *Calif.*

Provides ready access for inspection and maintenance in sheet-metal structures.



Size: Door diam is 1¾ in., accessible area of 1 by 1½ in.; metal thicknesses from 0.020 through 0.091-in. in standard gages; weigh from 0.33 to 1.15 oz.

Service: Providing easy opening access; one-half turn opens and removes doors; easily installed; doubler sheet eliminates necessity of making difficult cutout.

Design: Flush, rotating access door; doubler sheet of stainless steel or Alclad installed by riveting or spot welding; available without mounting holes or with holes spaced to conform with strength requirements and rivet patterns.

For more data circle MD-19, Page 199

BEARING LOCKNUTS 18

. . . have self-locking elastic inserts

Bearing Locknut and Machine Co., 831 *Bond St., Elizabeth, N. J.*

Self-locking feature of these nuts eliminates need for lockwashers and permits accurate bearing preloads.

Designation: Shurlock.

Size:

OD (in.)	Width (in.)	Nominal Bearing Bore (in.)	OD (in.)	Width (in.)	Nominal Bearing Bore (in.)
[illegible]	[illegible]	.6693	4 [illegible]	[illegible]	3.5433
1⅜	⅜	.7874	4 [illegible]	[illegible]	3.7402
1 [illegible]	⅜	.9843	4 [illegible]	⅞	3.9370
1½	½	1.1811	5	⅞	4.1339
1 13/16	½	1.3780	5 [illegible]	⅞	4.3307
2	[illegible]	1.5748	5 [illegible]	[illegible]	4.7244
2 [illegible]	[illegible]	1.7717	6 [illegible]	1	5.1181
2 7/16	[illegible]	1.9685	6 [illegible]	1 1/16	5.5118
2 [illegible]	[illegible]	2.1654	7 1/16	1⅛	5.9055
2 [illegible]	⅝	2.3622	7¾	1 3/16	6.2992
3 [illegible]	[illegible]	2.5591	8 [illegible]	1¼	6.6929
3 [illegible]	[illegible]	2.7559	8¾	1¼	7.0866
3 [illegible]	[illegible]	2.9528	9	1¼	7.4803
3 [illegible]	[illegible]	3.1496	9½	1 7/16	7.8740
4 [illegible]	[illegible]	3.3465			

Service: Locking antifriction bearings on shafts; will not loosen in service; require no keyways in shafts, or lockwashers; permit precise bearing preload adjustments; may be used to replace keyed locknuts if keyway is filled and threads rechased.

Design: Made of 1018 steel; face runout does not exceed 0.0005-in. total indicator reading; four slots spaced 90 deg for tightening or removal.

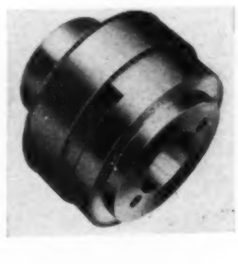
For more data circle MD-18, Page 199

FLEXIBLE COUPLINGS 20

. . . attach directly to flywheel

Lovejoy Flexible Coupling Co., 5001 *W. Lake St., Chicago* 44, *Ill.*

One end of these couplings is in flange form and has three or four tapped holes for fastening to a flywheel.



Designation: Type C, modified.

Size and Service: Driving shaft from flywheel; compensates for misalignment and absorbs vibration; no lubrication required; may be operated at higher speeds than shown in table;

Bore Diam Max (in.)	OD (in.)	Max Hp (at 100 rpm)	Bore Diam Max (in.)	OD (in.)	Max Hp (at 100 rpm)
2⅛	4¼	2.20	4	9 [illegible]	28.1
2⅜	4 13/16	4.88	4	9 [illegible]	33.3
2⅝	5½	7.00	4⅜	10 [illegible]	48.3
3⅛	6 [illegible]	11.00	4⅝	12 [illegible]	98.0
3⅛	8	16.5	5⅜	13⅞	136.0
3½	9	21.1	5⅞	14⅞	170.0

Design: Flexible coupling; one end in flange form for fastening to flywheel face of engines; drive is through 6 or 10 segments of flexible material; four types of material available for varying conditions; standard coupling includes shaft key seat; specials for splined shafts available.

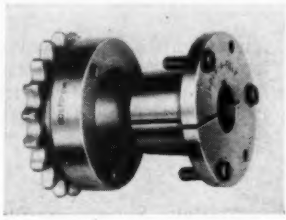
For more data circle MD-20, Page 199

NEW PARTS AND MATERIALS

SPROCKETS 21

. . . have interchangeable tapered bushings

Boston Gear Works, 14 Hayward St., Quincy 71, Mass.



The same size sprocket can be used on shafts from ½ to 2½ in. diam.

Designation: Shold-A-Grip.

Size: For ½ to 3 in. diam shafts; for No. 40, 60, 80 or 100 chain; sprockets have from 10 to 25 teeth.

Service: Power transmission, easily installed and removed from shafts; can be used with shafts as much as 0.005-in. under size.

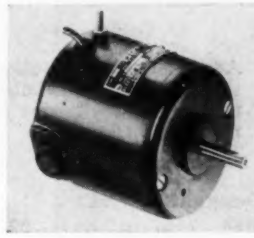
Design: Sprockets for roller chain drives; tapered split bushings are drawn into sprocket bore by cap screws, forcing bushing to grip both sprocket and shaft; puller holes in bushing for forcing bushing out of sprocket; made of machine steel; can be case hardened; bushings have square key seats.

For more data circle MD-21, Page 199

SERIES MOTOR 23

. . . can be submerged in water

EMC Div., Howard Industries Inc., Racine, Wis.



Totally enclosed and having permanently lubricated and sealed bearings, this motor withstands severe environmental conditions.

Designation: Model 710.

Size: 3¾ in. end bell to end bell; shaft diam is $\frac{5}{16}$-in.

Service: Delivers 1/15 to 1/30-hp; available for 6, 12, 24, 32 or 115 v ac or dc; withstands water submersion and a wide range of temperatures; requires no lubrication.

Design: Series wound electric motor; available with permanently lubricated and sealed sleeve or ball bearings; case is totally enclosed type, tightly sealed.

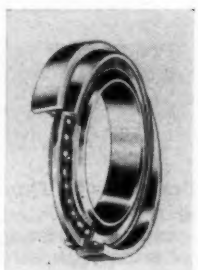
Application: Blowers or fans.

For more data circle MD-23, Page 199

SELF-ALIGNING BEARINGS 22

. . . accommodate structural deflections

Fafnir Bearing Co., New Britain, Conn.



A self-aligning outer ring allows these bearings to align themselves with the shaft even though the housing moves.

Designation: KP-BS series.

Size and Service: Supporting shafts and compensating for misalignment; require no lubrication;

Part No.	Bore (in.)	OD (in.)	Weight (lb)	Static Radial Load (lb)	Static Thrust Load (lb)
KP21BS	1.3130	2.250	0.20	5400	4400
KP23BS	1.4380	2.375	0.22	5800	4700
KP25BS	1.5630	2.500	0.25	6200	5000
KP29BS	1.8130	2.750	0.27	7000	5600
KP33BS	2.0630	3.000	0.30	8000	6400
KP37BS	2.3130	3.250	0.33	8700	7000
KP47BS	2.9380	4.125	0.64	12700	10200
KP49BS	3.0630	4.250	0.69	15200	12100

Design: Self-aligning ball; outer race fits inside ring having same curvature as race; bearings are prelubricated and sealed at the factory.

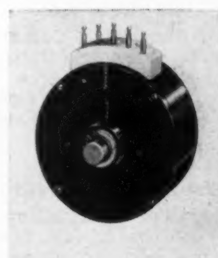
Application: Aircraft control torque-tube bearing.

For more data circle MD-22, Page 199

PRECISION POTENTIOMETER 24

. . . functions during 50g acceleration

G. M. Giannini & Co. Inc., 117 E. Colorado St., P.O. Box N, Pasadena 1, Calif.



Standard linearity tolerance is ±0.3% and special units of even higher linearity are available.

Designation: Model 85196.

Size: 1¾ in. diam; weighs 2½ oz with sleeve bearings, 3½ oz with ball bearings.

Service: Continuously varying electrical resistance; will dissipate 3 w at 25 C; operating temperature range of −54 to 71 C; maximum resistances from 2000 to 200,000 ohm; functions during 50*g* acceleration along any axis; 0.5 oz-in. torque required to rotate ball-bearing model.

Design: Wire-wound potentiometer; mechanical rotation can be 360 deg, or stop can be provided to give any rotation to 330 deg; standard electrical contact angle is 356 deg but can be as high as 360; syncro or screw-type mounting.

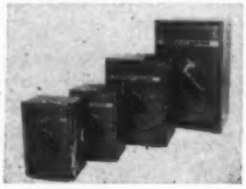
For more data circle MD-24, Page 199

NEW PARTS AND MATERIALS

INTERRUPTER SWITCH 25

. . . has gasketed enclosure

Trumbull Electric Dept., General Electric Co., Plainville, Conn.



Arc-quenching action of this switch prevents contact pitting thereby assuring long life.

Designation: HCI.

Size: $14\frac{3}{8}$ in. wide, $22\frac{3}{8}$ in. high and $11\frac{1}{16}$ in. deep.

Service: Interrupts 200 amp at 600 v; dust resistant; long contact life.

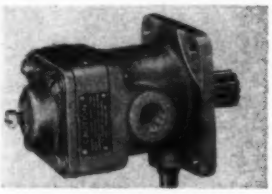
Design: Felt-gasketed steel enclosure meets NEMA 1-A specifications; front operating handle of aluminum; double-break contacts open and close with high speed and force; grid pins break arcs into series of smaller arcs and dissipate heat; available with or without provisions for fusing; also available in lower ratings.

For more data circle MD-25, Page 199

FUEL PUMP 27

. . . weighs only one pound

Romec Div., Lear Inc., Elyria, O.



An integral relief valve is externally adjustable to provide discharge pressures from 8 to 20 psi.

Designation: Series RD-7420.

Size: $2\frac{1}{2}$ by $2\frac{7}{16}$ by $3\frac{13}{32}$; weighs 1 lb; mounting holes on $1\frac{7}{8}$ in. centers; $\frac{1}{4}$-in. inlet and outlet ports; $\frac{1}{8}$-in. drain port.

Service: Pumping gasoline, diesel oil or special aromatic blends; operate at speeds to 4500 rpm; easily disassembled for servicing; capacity of 2 to 30 gph at 15 psi and 3700 rpm; operates in either direction of rotation.

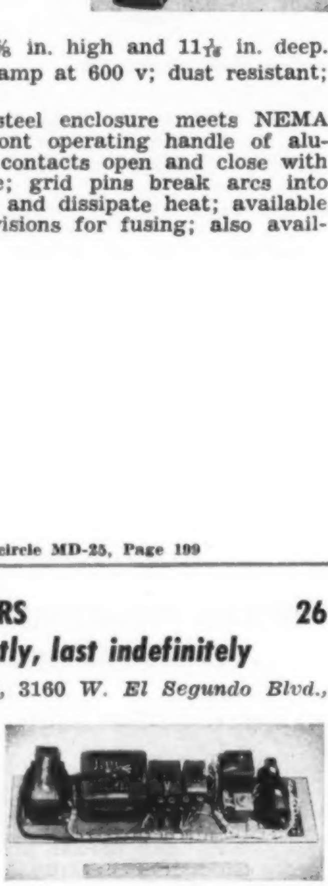
Design: Balanced vane pump; incorporates relief and by-pass valves; 12-tooth splined shaft per AND 2000, teeth have 20/40 pitch and 30 deg pressure angle.

For more data circle MD-27, Page 199

MAGNETIC AMPLIFIERS 26

. . . operate instantly, last indefinitely

Karl-Douglas Associates, 3160 *W. El Segundo Blvd., Hawthorne, Calif.*



These units function as highly efficient, low-cost devices in providing precision current control and amplification.

Size: Specially built for required service.

Service: Controlling and positioning variable speed motors of all sizes within ±1%, regulating both ac and dc generator voltages, amplifying minute power inputs of thermocouples, strain gages, etc., into measurable quantities, controlling time delays, servosystems, automatic battery chargers, reel controls for synchronizing or governing a battery of motor drives, arc welding controls, metering of dc voltages and currents, controlling rectifier voltages, controlling hydraulic transmissions, and audio amplifiers; contain no vacuum tubes; resist shock and vibration; little maintenance because of absence of moving parts or contact points; amplification of 1,000,000 possible; protected from heat, cold, humidity or fungus by heavy plastic coating; small in size.

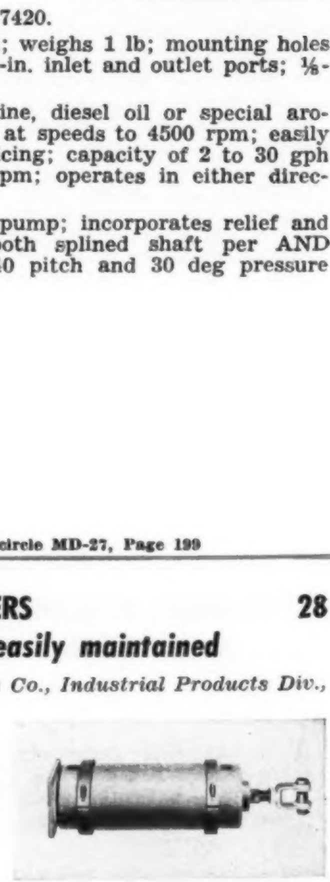
Design: Magnetic amplifier of self-saturating type; uses saturable-core reactor and selenium rectifier which precent the reactor from becoming demagnetized by the ac voltage supply; can be designed to operate from any single or polyphase ac supply voltage, varying from few volts to several hundred, and at frequencies ranging from the lowest power frequency to megacycles.

For more data circle MD-26, Page 199

PNEUMATIC CYLINDERS 28

. . . save space, easily maintained

Westinghouse Air Brake Co., Industrial Products Div., Wilmerding, Pa.



Foot, flange or pivot mounting adapt these cylinders to a wide variety of applications.

Designation: Type A.

Size and Service: Pushing or pulling; easily maintained; resist corrosion, sealed against dirt; length varies with stroke; 200 psi maximum recommended pressure;

Bore Diam (in.)	Max* Stroke (in.)	OD (in.)	Push-stroke Force (inlet air at 200 psi) (lb)
$1\frac{1}{2}$	45	$2\frac{5}{8}$	353
$2\frac{1}{4}$	30	$3\frac{1}{4}$	795
3	60	$3\frac{5}{8}$	1412
4	45	$4\frac{11}{16}$	2512
5	55	$5\frac{11}{16}$	3926
6	45	$6\frac{13}{32}$	5654
8	53	9	10052
10	42	11	15708

*May be increased if piston rod is in tension only.

Design: Double-acting pneumatic cylinders; heads retained by circular clamps, eliminating tie rods; heads, of aluminum, may be rotated to any desired position; piston rods of carbon or stainless steel; bodies of carbon steel or brass; 8 and 10 in. bore sizes made with stainless steel rod and brass body, other sizes as ordered; O-ring and cup type seals; may be cushioned at one, both or neither end of stroke; kits for foot, flange or pivot mounting available.

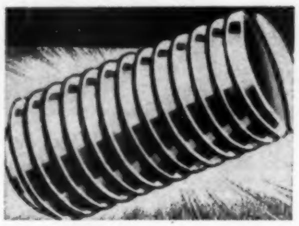
For more data circle MD-28, Page 199

NEW PARTS AND MATERIALS

SETSCREWS 29

. . . have increased holding power

Set Screw & Mfg. Co., 28 Main St., Bartlett, Ill.



Larger cup diam than that of standard setscrews makes fuller contact with shaft possible.

Designation: Nu-Cup.

Size: No. 2 through No. 10 and ¼, 5/16 and ⅜-in. diam; lengths ⅛ to 1 in.

Service: Holding shaft-mounted pulleys, gears, etc.; deep penetration; has high holding power; high resistance to reversal.

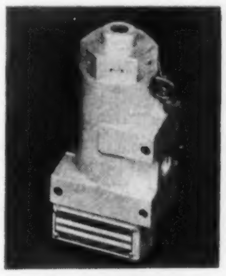
Design: Slotted headless and slabbed-head type setscrews; have large diam cup circle; made of hard alloy steel.

For more data circle MD-29, Page 199

RELIEF VALVE 31

. . . relatively insensitive to back pressure

Pantex Mfg. Co., Hydraulics Div., Pawtucket, R. I.



Relief pressure is constant over a wide range of back pressure.

Size: ⅜, ½ or ⅝-in. tube ports; standard AN6279 envelopes.

Service: May be set to relieve at pressures from 900 to 4500 psi; resists corrosion and attack by all commonly used hydraulic oils and fluids.

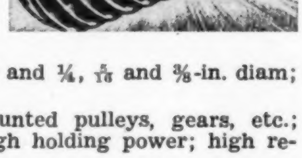
Design: Pressure relief valve; all operating parts of stainless steel except springs in some pressure ranges; valve housing of anodized aluminum; substantially the same as valve meeting MIL-V-5523 specifications; can also be made with steel housings.

For more data circle MD-31, Page 199

ELECTRICAL RESOLVER SYSTEM 30

. . . operates accurately over wide range

Ford Instrument Co. Div., Sperry Corp., 31-10 Thomson Ave., Long Island City 1, N. Y.



The resolver system assures adjustment of input/output transformation ratio and eliminates phase shift (resolver shown).

Size and Designation: Size 23 system uses either a basic resolver (2.25 in. diam) or a vector solver (2.25 in. diam); size 31 system uses either a basic resolver (3.10 in. diam), a basic bearing mounted resolver (3.625 in. diam) or a vector solver (3.10 in. diam).

Service: Providing resolution of mechanical and/or electrical scalar or vector inputs for computational devices, e.g., surface and antiaircraft fire control computers, offshore bombardment systems, navigational equipment; resolver system outputs used by computing systems to solve equations in automatic control systems; frequency, 400 ± 5 cps max; input voltage, 0.25 to 12 v; input impedance 1 megohm; transformation ratio (at 8.0 v input), $1.0000\angle 0° 0'$; sin error value, ±0.0006 max; cos error value, ±0.0010 max; interaxis error ±3'; temperature compensation from −60 F to +160 F; basic resolver handles one electrical and one mechanical input; vector solver handles two electrical and one mechanical input; bearing mounted resolver handles two mechanical inputs and one electrical.

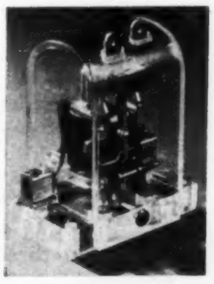
Design: Electrical resolver system composed of summing network box, high-gain computing amplifier and resolver.

For more data circle MD-30, Page 199

OVERLOAD RELAY 32

. . . combines time delay and fast operation

Heinemann Electric Co., 309 Plum St., Trenton 2, N. J.



A time delay period prevents operation of the relay on momentary overloads but permits instantaneous operation on high overloads.

Designation: Type C Silic-O-Netic.

Size: 1½ in. wide, 2¾ in. long, 3⅜ in. high; weighs 6 oz.

Service: Preventing damage to electrical equipment due to overloads; available for voltages to 440 v with coil ratings from 1 to 100 amp; standard response time at 125 per cent load is approximately 100 seconds, at 600 per cent load approximately 1 second; power consumption, 2 w; unaffected by ambient temperatures.

Design: Single-pole, single-throw overload; time-delay device is iron core in hermetically sealed tube filled with silicone liquid; overload draws magnetic core toward armature but motion is resisted by liquid to give time delay at low overloads; on extreme overloads, armature action is instantaneous; contacts of fine silver; contact blades of heat-treated phosphor bronze; coil terminals for 4 to 14 gage wire; screw-type contact terminals for 14 to 18 gage wire; sturdy molded phenolic housing.

For more data circle MD-32, Page 199

NEW PARTS AND MATERIALS

PLASTIC PROTECTIVE COATINGS 33

. . . applied by brushing, spraying or dipping

Flexrock Co., Protective Coating Div., 3698 Filbert St., Philadelphia 4, Pa.

Has excellent adhesion with no possibility of intercoat separation.

Designation: Flexcoat.

Service: Protecting against corrosion caused by atmospheric conditions, vapors, fumes, acids, alkalis, and spillage and splash of chemicals; can be applied over old paints; has good adhesion to metal, wood or concrete over wide temperature range; primer and top coat homogeneous; has wide range of colors to decorate and identify machines and pipelines.

Design: Plastic resin; vinyl resins and rubber resins formulated with acrylics; contains no oxidizing oils or resins; dries by solvent evaporation with no change taking place in film as it ages to lower its inertness to corrosive substances.

For more data circle MD-33, Page 199

PLASTIC CABLE CLAMPS 35

. . . flexible for easy installation

Holub Industries, Sycamore, Ill.

Made from pliable Saran plastic, these clamps can be easily opened to slide over wire, cable, pipe or tubing.

Size: All have 0.204-in. diam mounting hole; loop ID of ⅛, 3/16, ¼, 5/16, ⅜, 7/16, ½, 9/16, 19/32, ⅝, 11/16, ¾, ⅞, 1, 1⅛, 1 3/16 and 1¼ in.

Service: Supporting pipe, tubing, hose, wires or cables; will not burn or corrode; unaffected by prolonged immersion in water; resistant to mild acids and alkalis, chemicals and oil; have good abrasion resistance; inert to fungicidal attack.

Design: Cable clamps of Saran plastic; rounded edges prevent insulation damage; resilience eliminates need of lockwasher in many instances.

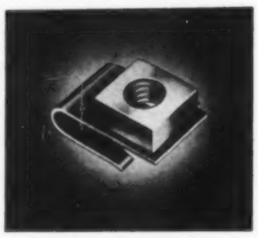
For more data circle MD-35, Page 199

NUT-CLIP FASTENER 34

. . . facilitate assembly of steel sheets

Prestole Corp., Toledo, O.

This fastener is simply clipped to the edge of sheet metal panels.



Designation and Size: 10-24, 12-24, ¼-20, ¼-28, 5/16-24 and ⅜-24 threaded nuts; all clips are of 0.035-in. material;

Part No.	Clip Length (in.)	Clip Width (in.)	Panel edge to center nut (in.)
751-7 A B or C*	⅞	⅝	7/16
751-9 A B or C	1	⅝	[illegible]
751-11 A B or C	1⅛	⅝	[illegible]
751-13 A B or C	1¼	⅝	[illegible]
751-15 A B or C	1⅜	⅝	[illegible]

* Suffix indicates panel thickness, A—0.030 to 0.070-in., B—0.065 to 0.105-in., C—0.100 to 0.140-in.

Service: Easily clipped to sheet-metal panels; provides multiple thread holding power.

Design: Nut-clip fastener assembly; ends of clip act as lock washer; finished in phosphate coat and oiled, other standard finishes available as specials.

For more data circle MD-34, Page 199

BROACH FIT BUSHINGS 36

. . . can be installed in low tolerance holes

Aeroquip Corp., Jackson, Mich.

These bushings will work satisfactorily in holes with a maximum tolerance of 0.002-in. while a conventional bushing must be used in a hole having a maximum tolerance of 0.0005-in.

Size: 1/16 to ¾-in. bore in headless type, 1/16 to ½-in. bore in headed type; lengths from ¼ to 1 in., OD of all sizes is ⅛-in. larger than bore.

Service: Providing wearing surface in plastics, cast and other metals; easily installed and locked in position; can be removed and replaced without reworking hole; resist rust and corrosion.

Design: Bushings of hardened steel; treated with black oxide penetrate; outer surface is series of small cutting edges which broach their way into position; material cut away as bushing is installed is held in chip retainer groove in outer surface of bushing; pilot 0.0025-in. smaller than OD assures correct alignment when bushing is installed.

For more data circle MD-36, Page 199

JOHNSON

POWDER METAL

BEARINGS AND PARTS

for certain applications nothing can beat them

The porous structure of Johnson Ledaloyl bearings and parts permits oil impregnation during manufacture, making them self-lubricating. In operation, the oil is metered to the shaft and reabsorbed when the shaft is at rest. Should your specific application be difficult or impossible to lubricate regularly, here is your answer.

Other industrial uses are: Self-alignment, low-cost bearings or special parts, applications where heavy duty service is not a factor. Ledaloyl bearings and parts are pressure molded to shape and size . . . no machining necessary . . . hence their low unit cost in large quantities. In numerous applications they give long, troublefree service. Johnson engineers will gladly help you determine whether you can use Ledaloyl bearings or parts. Write for an appointment.

JOHNSON BRONZE COMPANY
525 South Mill Street • New Castle, Pa.

Ledaloyl
SELF LUBRICATING

POPULAR sizes of straight, flanged and self-aligning bearings are available from stock. Write for catalog.

JOHNSON JB BEARINGS
Sleeve-Type

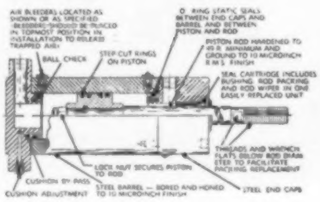
JOHNSON BRONZE PRODUCES ALL TYPES OF SLEEVE BEARINGS: BRONZE-ON-STEEL, copper lead • STEEL BACK, babbitt lined • BRONZE BACK, babbitt lined • CAST BRONZE, plain or graphited • SHEET BRONZE, plain or graphited • CAST ALUMINUM ALLOY • ALUMINUM-ON-STEEL.

NEW PARTS AND MATERIALS

HYDRAULIC CYLINDERS 37

. . . designed to resist abrasive wear

Hydro-Line Mfg. Co., 707 19th St., Rockford, Ill.



Hardened piston rods and rod scrapers assure long service life where abrasive dusts cannot be avoided.

Designation: Series J.

Size: 1½ to 10 in. bore, strokes to 6 ft.

Service: Working pressures to 2000 psi or 3000 psi in nonshock service; resist damage due to rough handling; easily serviced; for operation with oil or water.

Design: Comply with all JIC specifications; steel barrels are bored and honed to 10 microinch finish; piston rods are hardened to 49 Rockwell C and ground to 10 microinch finish; O-ring seals between end caps and barrels; wrench flats on ends of piston rods facilitate disassembly; available with flange, foot, eye or trunnion mountings.

For more data circle MD-37, Page 199

PULSE-FORMING NETWORK 39

. . . can function at 200 C

PCA Electronics Inc., 6368 Longpre Ave., Hollywood 28, Calif.

Though normal ambient temperature range is −65 to 105 C, special models function at even higher temperatures.

Designation: PFN 7030B.

Size: $\frac{5}{16}$-in. diam, 1$\frac{7}{16}$ in. long; 1¼ in. long leads.

Service: Forms 0.15-microsecond pulse; impedance, 1050 ohm; resists corrosion and moisture.

Design: Pulse-forming network; potted in special resin compound; No. 22 solid copper, tinned leads; specials for pulse widths from 0.02 to 20 microseconds available.

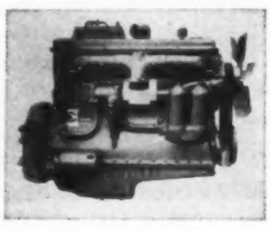
Application: Radar, guided missile, and computer circuits.

For more data circle MD-39, Page 199

GASOLINE-BUTANE ENGINE 38

. . . for trucks or industrial use

Hall-Scott Motor Div., ACF-Brill Motors Co., Berkeley, Calif.



This engine can be supplied to run on gasoline or butane and is easily modified to run on either fuel.

Designation: Model 1091.

Size: 62⅝ in. long, 47⅞ in. high, 30½ in. wide; dry weight of engine and accessories is 2300 lb; SAE No. 1 flywheel housing.

Service: Rated 285 bhp at 2200 rpm for truck service when operated on gasoline, 318 bhp max at 2200 rpm, 945 lb-ft max torque at 1400 rpm; rated 320 bhp at 2200 rpm for truck service when operated on butane, max bhp is 345 at 2200 rpm, max torque is 1070 lb-ft at 1200 rpm.

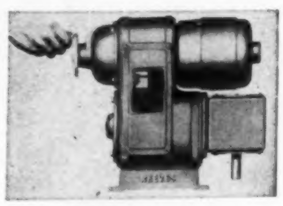
Design: Six-cylinder, four-cycle; 5¾ in. bore by 7 in. stroke, total displacement of 1091 cu in.; cylinders cast en bloc of chrome-nickel-molybdenum cast iron; 7 main bearings; 12 crankshaft counterweights; figure 8 combustion chamber and swirl type valve ports; gasoline engine has compression ratio of 6.4 to 1; butane engine has compression ratio of 8.8 to 1; includes oil filters and oil cooler; also available with SAE No. ½ or 2 flywheel housings.

For more data circle MD-38, Page 199

VARIABLE SPEED DRIVE 40

. . . incorporates right-angle speed reducer

Reeves Pulley Co., Columbus, Ind.



Available in vertical or horizontal models with speed ratios from 2 to 1 through 10 to 1.

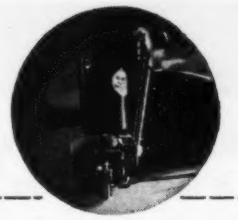
Designation: No. 1101-R.

Size: Vertical model is 9⅝ in. wide, 19¾ in. high and approximately 25 in. long; horizontal model is 11 in. high, 16⅞ in. wide and approximately 25 in. long; output shaft is 1¼ in. in diam and has ⅜ by $\frac{3}{16}$-in. keyway.

Service: Deliver ¼, ⅓, ½ or ¾ hp; available with speed variation of 2, 3, 4, 5, 6, 8 or 10 to 1; maximum output speeds of 279, 227, 183, 148, 122.5, 99, 80, 65.6, 56, 45.3, 37, 30, 24.5 or 20 rpm; for heavy-duty, continuous operation.

Design: Combination motor, variable-speed transmission and right-angle speed reducer; motors are standard face-mount type; transmission is Reeves V-belt and variable-pitch pulley type; gear reducer has alloy steel worm and gear; can be assembled with output shaft up, down or at right angles; may be obtained splashproofed or dustproofed; standard control is manual on unit, but remotely operated electric, hydraulic or pneumatic controls are also available.

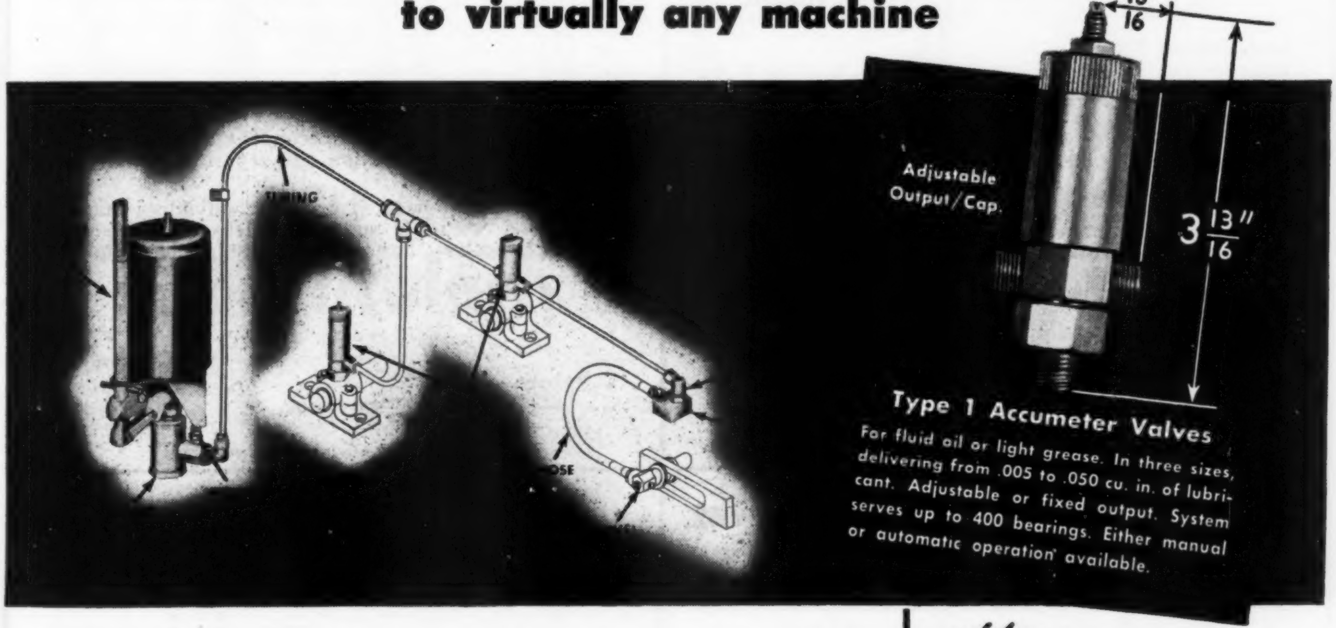
For more data circle MD-40, Page 199



Designed... **to eliminate hit-or-miss machine lubrication**

ALEMITE Accumeter®
CENTRALIZED LUBRICATION

extends the protection of automatic lubrication to virtually any machine



Centralized lubrication with Alemite Type I Accumeter can make your machines produce more, last longer, and cost less to run—*impressive savings at low cost!* This simple, single-line system is completely versatile—easy to design, easy to build into any machine because valves fit directly on bearings, replacing grease fittings, oil cups or reservoirs.

In seconds, in a fraction of the time required for hand lubrication, Alemite Accumeter Lubrication System delivers the exact, measured amount of clean oil or grease *from one central point* to all bearings of a machine. The machine keeps operating—no production time lost—no bearings are missed. No wonder 95% of big plants buying machine tools specify *centralized lubrication!*

Type 1 Accumeter Systems serve single machines or groups of machines with semi-automatic or fully automatic lubrication. It is just one of three types of Accumeter Systems made by Alemite to meet your exacting requirements.

offers...
ALL THESE ADVANTAGES!

- **Eliminates shutdown time for lubrication. *Adds* productive time to machine output.**
- **Seals completely against dirt, grit, water all the way from "Barrel-to-Bearing."**
- **Prevents bearing troubles due to neglect or use of wrong lubricant.**
- **Services *all* bearings—including those inaccessible or dangerous—in one operation.**
- **Avoids work spoilage and bearing repairs due to over-lubrication.**

FACTORY-TESTED . . . FIELD-PROVED

Proved in the field. Exhaustive tests showed *no variation* in the amount of lubricant discharged . . . even after 73,312 lubrication cycles, *equal to 122 years of twice-a-day service.*

ALEMITE
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A PRODUCT OF SW STEWART WARNER

Free—**Alemite Accumeter Catalogue and Engineering Data Book.**

ALEMITE, DEPT. R-33
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Please send me my free copy of the Alemite Accumeter Catalogue and Engineering Data Book.

Name ______________________

Company ______________________

City ____________ State ____________

NEW PARTS AND MATERIALS

HYDRAULIC CYLINDERS 41

... have cushion effect at both ends of stroke

Fishburne Machine Co., P.O. Box 6006, Asheville, N. C.

Screwed-on end castings eliminate leakage.

Designation: Sealdraulic.

Size: 1, 1½, 2, 2½, 3, 3½, 4, 4½, 5, 6, 7 or 8 in. bores; stroke as required.

Service: 2000 psi working pressure; will not leak; resist wear; easily installed and piped; working medium, hydraulic oil.

Design: Single or double-action cylinders; end castings screw on, allowing ports to be positioned at any point for connecting piping; end castings sealed by gaskets; piston rod wiper prevents entry of dirt; available for flange, foot, trunnion or centerline mounting at either rod or head end.

For more data circle MD-41, Page 199

ELECTROMECHANICAL COUNTER 43

... requires small hole in mounting panel

Landis and Gyr Inc., 45 W. 45th St., New York 36, N. Y.

An opening of only ¾ by 1¼ in. is required for mounting this counter.

Size: 4 in. long, approximately ¾-in. high and 1¼ in. wide; 5/32-in. high numerals.

Service: Counts to 9999; actuated by electrical impulse; for 4 to 60 v dc operation; power requirement, 1.4 to 2.5 w depending on voltage; maximum counting rate is 10 per second; impulses must be of 40 millisecond duration and separated by at least 50 milliseconds.

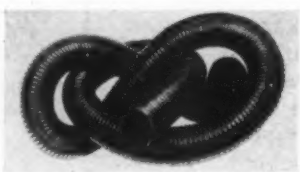
Design: Solenoid-operated counter; advances one-half unit when circuit is made, completes advance when circuit is broken; has two drilled holes for mounting.

For more data circle MD-43, Page 199

FLEXIBLE HOSE 42

... has increased fatigue resistance

American Ventilating Hose Co., 100 Park Ave., New York, N. Y.



Tensile strength and resistance to abrasive wear are also better than in hose previously manufactured by this company.

Designation: Flexaust CWL, CWC, CWY.

Size: 1¼ to 12 in. ID; OD is ¼-in. larger than ID for sizes to 9 in., 5/16-in. larger for 10 to 12 in. sizes; stock length is 25 ft; weight per ft of 1¼ in. ID is approximately 0.15-lb, of 12 in. ID approximately 2.7 lb.

Service: Ducting air, gases or airborne materials; CWL is airtight to 40 in. of water pressure or vacuum; CWC and CWY are airtight to 50 in. of water pressure or vacuum; higher pressures may be handled, if minor seepage is permissible; recommended temperature limits are −40 to 200 F for CWL, −40 to 220 F for CWC and CWY.

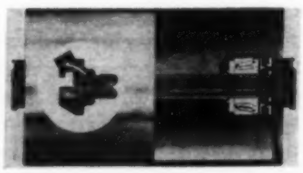
Design: Hose of neoprene coated fabric reinforced with 90,000 to 120,000 psi tensile strength wire; cotton sheeting used in CWL, cotton drill in CWC, nylon fabric in CWY; minimum wall thickness is six layers of material; lengths longer than stock available as specials.

For more data circle MD-42, Page 199

CONVEYOR BELT IDLERS 44

... have prelubricated, sealed bearings

Continental Gin Co., Industrial Div., Birmingham 2, Ala.



Operation for as long as three years without lubrication is claimed to be possible.

Designation: Type UST.

Size: 5 and 6 in. diam std; heavy duty rollers, 6 and 7 in. diam; std for belt widths of 14, 16, 18, 24, 30, 36, 42, 48, 54 and 60 in.; heavy duty for belt widths of 36, 42, 48, 54 and 60 in.

Service: Prolong belt life by preventing grease leakage onto belt; easily disassembled for cleaning and relubrication.

Design: Troughing and return conveyor belt idlers; troughing idlers made up of three rolls and supporting frame, return idlers are single roll and mounting brackets; rolls of fusion-welded steel tubing or centrifugally cast tubing with induction-welded Meehanite heads; sealed and lubricated Timken tapered roller bearings have Garlock seals; frames are heavy malleable-iron brackets, welded to inverted angle; heavy duty idlers have 50 to 100% heavier roll shells, heavier shafts and heavier bearings.

For more data circle MD-44, Page 199

ENGINEERING DEPARTMENT

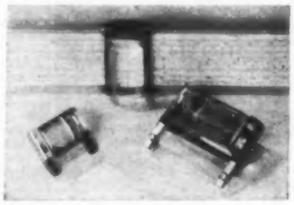
EQUIPMENT

For additional information on this new equipment, see Page 199

DOUBLE MAGNIFIER 45

. . . for duplex slide rules

Flatto Management Co., 70 W. 40th St., New York 36, N. Y.



Permits accurate readings on both sides of slide rule.

Designation: P. E. G. Duplex Magnifier.

Size: For slide rule widths $1\frac{13}{16}$ in., $1\frac{5}{8}$ in., $1\frac{11}{16}$ in. and $1\frac{3}{8}$ in.

Service: For reading both sides of duplex slide rules; magnifying power, $2\frac{1}{2}$ times, insuring measurement accuracy; fits 90% of duplex slide rules in use.

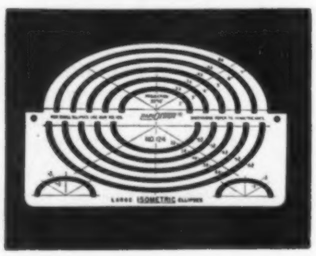
Design: Double magnifier, consisting of two precision-ground glass magnifying lenses; magnifier folds and fits in chamois bag to avoid scratching lenses when not in use; special version for 6 in. pocket duplex rules with magnifying power of 3 times.

For more data circle MD-45, Page 199

PLASTIC TEMPLATE 46

. . . for large isometric ellipses

Rapidesign Inc., P.O. Box 592, Glendale, Calif.



Supplements No. 123 Rapidesign isometric ellipse template (MACHINE DESIGN, September, 1952, Page 200.)

Designation: 124.

Size: 10 in. wide; 6 in. high; 0.080-in. thick.

Service: For isometric drafting; 25 ellipses, $\frac{1}{8}$-in. increments from $1\frac{1}{2}$ in. to 2 in., $\frac{1}{4}$-in. increments from 2 in. to 7 in.; dimensions given refer to isometric axes—actual size along large axes is larger, i.e., $8\frac{1}{2}$ in. for 7-in. ellipse.

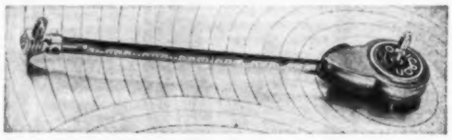
Design: Made of mathematical quality plastic; cutouts are precision milled; pencil allowance for accuracy.

For more data circle MD-46, Page 199

BEAM COMPASS 47

. . . has direct-reading scale

A. Partrick Co., P.O. Box 28, Westwood, N. J.



Parallelism between center pin and scriber is assured with steel beam on edge.

Designation: Omicron.

Size: For up to 144-in. diameter circles.

Service: General purpose drafting; automatically provides positive locking at any dimension; manual pumping of locking lever provides minute adjustments; no separate parts to put together.

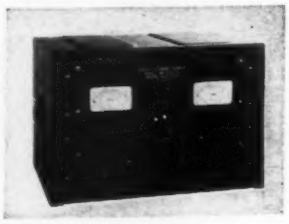
Design: Steel extension rule with scriber at end.

For more data circle MD-47, Page 199

DC POWER SUPPLY 48

. . . regulated by magnetic amplifier

Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif.



Features no tubes and accurate regulation from no load to full load.

Designation: MR 532-15.

Size: 22 in. wide, $14\frac{1}{2}$ in. high, 17 in. deep; weight, 125 lb.

Service: Rated at 5 to 32 v dc and 15 amp continuously; regulation $\pm 1\%$ for dc load variations from no load to full load; stabilized for ac line variations from 105-125 v; ripple, 1% max.

Design: Magnetic amplifier regulated; has magnetic circuit breaker on dc side with time delay provision; has ac on-off switch; provided with $4\frac{1}{2}$ in. ammeter and voltmeter; mounted in bench-type cabinet; adaptable to 19-in. rack panel mounting; gray wrinkle finish.

For more data circle MD-48, Page 199

1,000,000

INDUSTRIAL ENGINES

built in ONE year

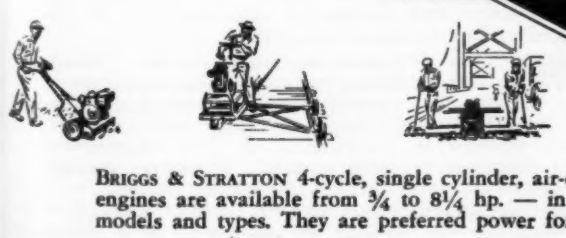
It's a new world production record — never before accomplished. For 33 years BRIGGS & STRATTON has been establishing a long list of firsts. And now, in 1952, another is added.

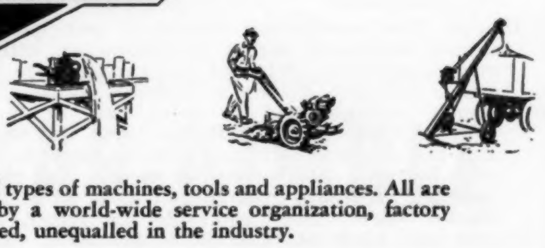
BRIGGS & STRATTON is recognized as the pioneer and the leader in its field . . . setting new standards, year after year in engineering, in design, in engine performance and in precision mass production.

Whether you are a manufacturer, dealer or user of gasoline engine powered equipment — you are assured of top performance when you specify BRIGGS & STRATTON 4-cycle, single cylinder, air-cooled engines. They are the "preferred power" value all over the world.

BRIGGS & STRATTON CORPORATION
Milwaukee 1, Wisconsin, U.S.A.

4 CYCLE
BRIGGS & STRATTON
GASOLINE ENGINES





BRIGGS & STRATTON 4-cycle, single cylinder, air-cooled engines are available from ¾ to 8¼ hp. — in many models and types. They are preferred power for hundreds of types of machines, tools and appliances. All are backed by a world-wide service organization, factory supervised, unequalled in the industry.

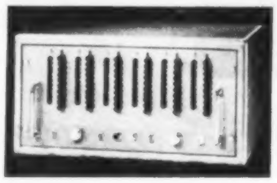
In the automotive field, too, Briggs & Stratton is the recognized leader — and the world's largest producer of locks, keys, and related equipment.

ENGINEERING DEPARTMENT EQUIPMENT

ELECTRONIC PRESET COUNTER 49

. . . for three types of counting operations

Berkeley Scientific Co. Div., Beckman Instruments Inc., 2200 Wright Ave., Richmond, Calif.



Output information is produced at a preset count for automatic control or to give a signal.

Designation: 5422, 5423, 5424, 5425, 5426.

Size: Two and three decade—16⅝ in. wide, 10¼ in. high, 13 in. deep; four, five and six decade—20¾ in. wide, 10½ in. high, 15 in. deep.

Service: For counting electrical pulses at rates from 0 to 40,000 per second; at preset count, unit produces pulse signal, resets and repeats indefinitely; output information can be obtained in form of positive pulse and relay closure if preset count is reached at rate less than 10 times per second; will operate as straightforward counter to capacity of unit; will count to preset number and stop; count capacity—1 to 100, 1 to 1000, 1 to 10,000, 1 to 100,000, 1 to 1,000,000; input sensitivity, ±1 v peak with respect to ground, at least 2 microsecond duration; input impedance, 1 megohm; power requirement, 117 v ac, ±10%.

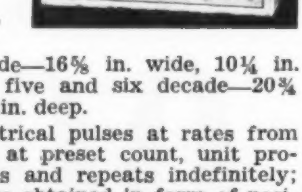
Design: Input circuit, electronic gate, cascaded presettable decimal counting units and output circuitry; input events are amplified, shaped and used to drive cascaded decade units.

For more data circle MD-49, Page 199

HIGH-SPEED RECORDER 50

. . . for electroacoustical measurements

Sound Apparatus Co., Stirling, N. J.



Makes permanent, continuous record of intensity variation of electrical signals over wide frequency range.

Designation: HPL.

Size: 16 in. wide, 16 in. high, 12 in. deep; weight, 35 lbs, chart paper, 2½ in. wide.

Service: For laboratory or field measurements of reverberation, sound intensity, sound decay, loudness, sound absorption, vibration, noise; records db intensities from 0 to 100; input impedance—10,000 ohms; frequency response, 20 to 200,000 cps—1 db; sensitivity, adjustable from 7 to 12 mv; paper speeds—1, 10 and 50 mm per second; two stylus speeds, 0.14 mm per second and 0.5 mm per second for full scale movement; power requirement—115 v, 60 cycles, 200 w.

Design: Servomechanism operation principle; input signals impressed across potentiometer; attenuator output amplified, detected and compared to dc reference voltage; difference between signal and reference voltage used to drive pair of magnetic clutches that control slider on input potentiometer and pen stylus; static pen position depends on balance between detector output voltage and reference voltage; recording scale depends on input potentiometer taper; interchangeable db, linear, square-root and phon potentiometers available; extension shaft provided for driving remote oscillator or analyzer.

For more data circle MD-50, Page 199

RECORDING CAMERA 51

. . . versatile, compact and lightweight

J. A. Maurer Inc., Photographic Instrumentation Div., 37-01 31st St., Long Island City 1, N. Y.

Records at automatically controlled intervals.

Designation: Auto Camera Mark 3 A and 3 B.

Size: 8⅞ in. long, 3⅜ in. wide, 4 in. high.

Service: For time-lapse recording, photomicrography, stereo and normal photomacrography, and aircraft instrument recording; records at intervals from ¼-second to as long as desired; automatically timed by electrical pulses; exposes 21 ft of 35-mm film per winding; Mark 3A copies 200 pictures on 1 x 1 in. frames; Mark 3 B copies 300 Pictures on ¾ x 1 in. frames; 5 shutter speeds from 1/10-second to 1/200-second and "time" exposure; may be controlled manually; field of view, 35 deg.

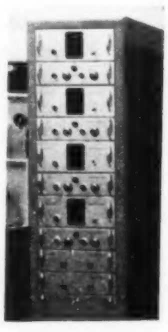
Design: Pulse-operated, spring-powered; front or base mounted; film held in special cassettes; powered by spring-wound motor; exposure and film transport actuated by electrical pulses; electrical contact provided for external exposure indication or flash light-source; standard lens is 36-mm focal length f/3.5 in graduated focusing mount; standard lens available in special antivibration focusing mount; other lenses available; special models of camera have 6 and 9 in. lenses; accessories include intervalometers, power supply units for 100 v 60 cycle ac, photomicrograph stands, and focusing magnifiers.

For more data circle MD-51, Page 199

ANALOG-TO-DIGITAL CONVERTER 52

. . . eliminates reading analog plots

Consolidated Engineering Corp., 300 N. Sierra Madre Villa, Pasadena 8, Calif.



Converts test measurements directly to numerical form.

Designation: SADIC.

Service: Converts test measurements from pressure pickups, thermocouples and strain gages directly to numerical values from 000 to 999; digital output, indicated by lighted panels, can operate readout equipment such as card punches, electric typewriters, adding machines, binary type computers and magnetic storage drums; can be used on any device or structure which reaches semistabilized conditions in actual operation; maximum measurement frequency, 1 per second; accuracy, 1 part in 1000; 1 microvolt sensitivity; can convert one or several measurements simultaneously; any number of channels may be assembled and expanded at any time.

Design: Specially designed, decimally divided Thompson-Varley self-balancing potentiometer; consists of three independent, bidirectional, ten-position stepping switches which vary a highly stable dc reference voltage in increments of 1/10 (hundreds), 1/100 (tens) and 1/1000 (units); stepping switches are servo-adjusted so potentiometer output voltage equals analog input signal; ratio of analog input to reference voltage is expressed as a three-digit decimal obtained from positions of potentiometer arms; power supply, 105-125 v, 60 cycles.

For more data circle MD-52, Page 199

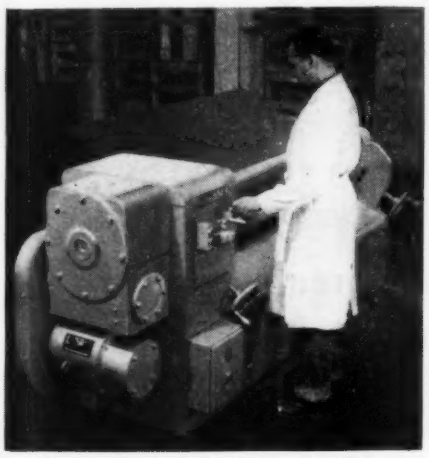
Advertisement

Brakemotor Prevents Drift, Saves Space on Niagara Bending Rolls

Use of a motor incorporating a spring-applied, electromagnetically released brake as an integral part of the motor design is an important factor in the simple, positive finger-tip control of the bending rolls produced by Niagara Machine & Tool Works, Buffalo, N. Y.

In the neutral position, rolls are instantly stopped by the action of the Brakemotor. This feature prevents drifting or overcoasting of the work in the rolls and thus permits more accurate operation. The fast, precise action of the brake allows work in the rolls to be reversed rapidly and frequently, without kicking out the thermal overload relays, as might occur in reversing by plugging.

The Brakemotor also permits jogging in short increments. The operator has complete and accurate control at all times.



Precise control of this Niagara Bending Roll is made possible by the Star-Kimble Brakemotor shown at lower left of machine

Saving in Frame Sizes

The Brakemotors used on these bending rolls are specially engineered to meet the speed and torque requirements of the application. As a result, Niagara has been able to use smaller frame sizes than would be possible with conventional designs.

In bending roll service, an extremely high torque is required when the plate is first started through the rolls. In the Brakemotors used on a typical size of Niagara Bending Roll, a 7½ hp motor provides the same starting torque as a 15 hp motor. Moreover, this 7½ hp motor is built in a smaller than standard frame size.

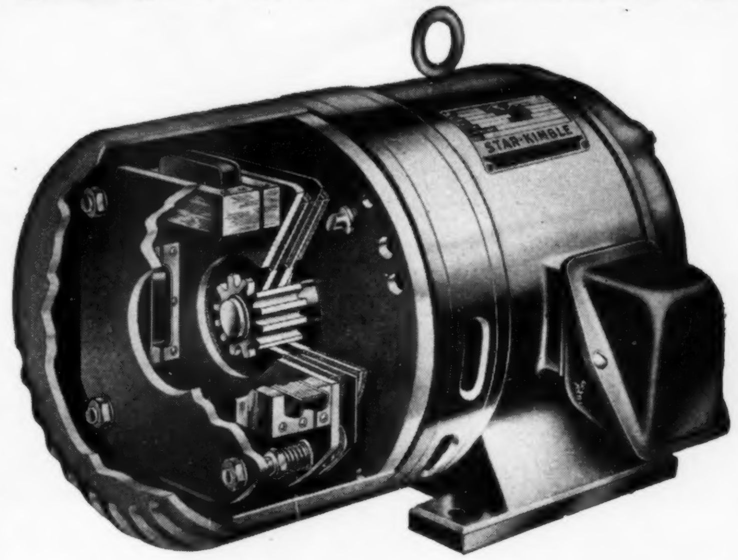
These features of fast, accurate stopping, reversing and inching on short cycles and smaller frame sizes are made possible by the brake action which eliminates the need for plugging and by the added safety factors for heavy duty which are built into the motors.

The Brakemotors are built by Star-Kimble Motor Division of Miehle Printing Press and Mfg. Co., 201 Bloomfield Avenue, Bloomfield, N. J. Complete details are given in Bulletin B-501-A, copies of which are available on request from the manufacturer.

STOP! START STOP! START STOP! START STOP!

START STOP! START STOP! START STOP! START

Instantaneous **STOPS!** Drag-free **STARTS**



START STOP! START STOP! START STOP! START

STOP! START STOP! START STOP! START STOP!

minute after minute YEAR AFTER YEAR with Star-Kimble Brakemotors

That extra-large brakelining area you see brings a Star-Kimble Brakemotor and its connected load to an *extra-fast stop*—as short as a fifth of a second from full speed to standstill if desired.

And the small air gap contributes to *equally fast starts.* Brake is released the instant motor current is switched on—equipment starts without drag.

That's the story of a *single* Star-Kimble stop-start cycle. And the experience of user after user *proves* that Star-Kimble Brakemotors *maintain* the same split-second stops, the same smooth starts, through hundreds of thousands of cycles. In reversing service, conventional plugging methods with a typical 5 hp motor allow only 3 starts per minute. With a Star-Kimble Brakemotor, the figure is boosted to 10!

Of course, every Star-Kimble Brakemotor is a compact, integral unit designed to save space—and give rugged, dependable performance. One manufacturer—one responsibility.

For the full story, write for Bulletin B-501-A

STAR-KIMBLE
MOTOR DIVISION
EHLE PRINTING PRESS AND MFG. CO.
201 Bloomfield Avenue Bloomfield, New Jersey

Contact **KAYDON** of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER

Photo by courtesy of Chrysler Delaware Tank Plant

Dependable KAYDON BEARINGS in world's greatest tank!

Some details of performance of the new Patton T-48 tank may remain closely guarded secrets. but now it can be told that KAYDON created the initial pilot-bearings for its gunmounts and cupola.

More than merely a masterpiece in tank engineering, the Patton 48 is also an outstanding economic achievement... Army's most economically produced tank ... resulting from fine teamwork of industry and labor.

Today, manufacturers of tanks ... guided by KAYDON ... are also producing these big super-precision bearings. Vital precision facilities thus are multiplied to speed production.

The Patton 48 ... speedy, most mobile of all tanks ... is a symbol of insurance for peace through strength! Manufacturers contributing to this achievement take pride in confidence that America's industrial brains and skill, mobilized in a democracy, can meet any challenge! The Patton 48's are here ... and they came fast!

So big! This super-precision turret bearing is so big that these four beauties stood comfortably inside only a portion of the 7-foot diameter to have their picture taken. • KAYDON also created the initial pilot-bearings (28.333" I.D. x 33.375" O.D. x 2.875" section) for cupolas of Patton T-48's. • *Both sizes of bearings were uniquely engineered with internal gears cut integral with the inner race.*

• • •

In many types of heavy-duty industrial machinery and war equipment, unusual KAYDON Bearings have been designed to make tough jobs easier, with dependable, controlled precision.

We'll be glad to work with you on difficult bearing problems.

THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

KAYDON Types of Standard and Special Bearings:
Spherical Roller • Taper Roller • Ball Radial • Ball Thrust • Roller Radial • Roller Thrust • Bi-Angular Bearings

PRECISION BALL AND ROLLER BEARINGS

MEN OF MACHINES

William H. Bennett

The Hydraulic Press Mfg. Co., Mount Gilead, O., has announced the promotion of **William H. Bennett** to the position of director of engineering. Mr. Bennett first joined the company in 1939 on a specialized training program from the University of Cincinnati and thereby received a broad practical knowledge of hydraulics in actual shop practice as well as engineeering. Upon receiving his mechanical engineering degree in 1943, he returned to the company. Mr. Bennett has also served as chief of the Forge and Press Equipment section of the Metalworking Equipment division of the National Production Authority in Washington.

♦

Ford Instrument Co., division of the Sperry Corp., Long Island City, N. Y., has appointed **Henry F. McKenney** as chief engineer. A graduate of the University of Cincinnati, Mr. McKenney came to the company eleven years ago as a test engineer. He entered the design engineering department shortly thereafter and has specialized in airborne equipment. For the past two years he has served as assistant chief engineer.

♦

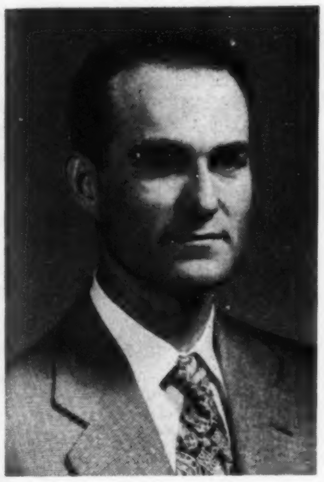
Cyril G. Veinott has joined the Reliance Electric & Engineering Co., Cleveland, as consulting engineer on ac machinery. Dr. Veinott is responsible primarily for the development and improvement of design methods and related engineering work on both standard model and special purpose ac motors. He comes to Reliance from the Westinghouse Electric Corp. where, for the past 25 years, he has been engaged chiefly in small motor engineering.

♦

To act as supervisor and technical consultant for the design of commercial and amateur radio receivers, **Leslie Norde** has joined the Hammarlund Mfg. Co. Inc., New York, as chief receiver engineer. He previously served for approximately five years as senior

project engineer at Northern Radio Corp., supervising the design of space diversity receivers and carrier shift radio teletype transmitting equipment. From 1944 to 1947, Mr. Norde was associated with Press Wireless Mfg. Co. as a development engineer, where for about two years he was supervising engineer of the development laboratory, with responsibility for the initial electrical designs of radioteletype and facsimile receiver and transmitter systems.

♦



Robert C. Rodgers

New assistant Editor of MACHINE DESIGN, **Robert C. Rodgers** is introduced in "Over the Board," Page 4 of this issue.

♦

Francis John Zimmerman has joined the mechanical division of Arthur D. Little Inc., Cambridge, Mass. He was formerly a research assistant at Massachusetts Institute of Technology.

♦

Cledo Brunetti

Cledo Brunetti has accepted an executive research post with the mechanical division of General Mills Inc., Minneapolis. A graduate of the University of Minnesota, Dr. Brunetti received his Ph.D. in electrical engineering there in 1937. Associated with the National Bureau of Standards in Washington, D. C., for eight years, he was chief of the engineering electronics section when he left NBS to join Stanford Research Institute in 1949. He served as associate director of the Institute. Dr. Brunetti's work at General Mills will include setting up a new general research laboratory as well as industrial development of the company's mechanical division.

♦

E. William Place, member of the engineering department of Beckman & Whitley Inc., San Carlos, Calif.,

has been promoted to the position of project engineer. Before joining this company he was engaged in design and project engineering activities with Carter Carburetor Corp., Jackson and Moreland, Brewster Aeronautical Corp. and the Air Technical Service Command of the U. S. Air Force.

•

New chief engineer of Taylor Instrument Companies, Rochester, N. Y., is **Ralph E. Clarridge.** He replaces **Karl H. Hubbard,** who was named technical director. Mr. Clarridge, a graduate of Ohio State University, has been associated with the company since 1930. He started in the research department as a physicist and transferred four years later to the application engineering department, where he was concerned with application of the company's line of industrial process control instruments to the petroleum and canning industries. Succeeding Mr. Clarridge as manager of the application engineering department is **George E. Howard,** formerly assistant manager.

Ralph E. Clarridge

Mr. Hubbard joined the company in the research department in 1928 and became head of the department in 1931. From 1938 to the present time he served as chief engineer. In his new capacity as technical director, he will act as technical consultant, with responsibility for research activities.

•

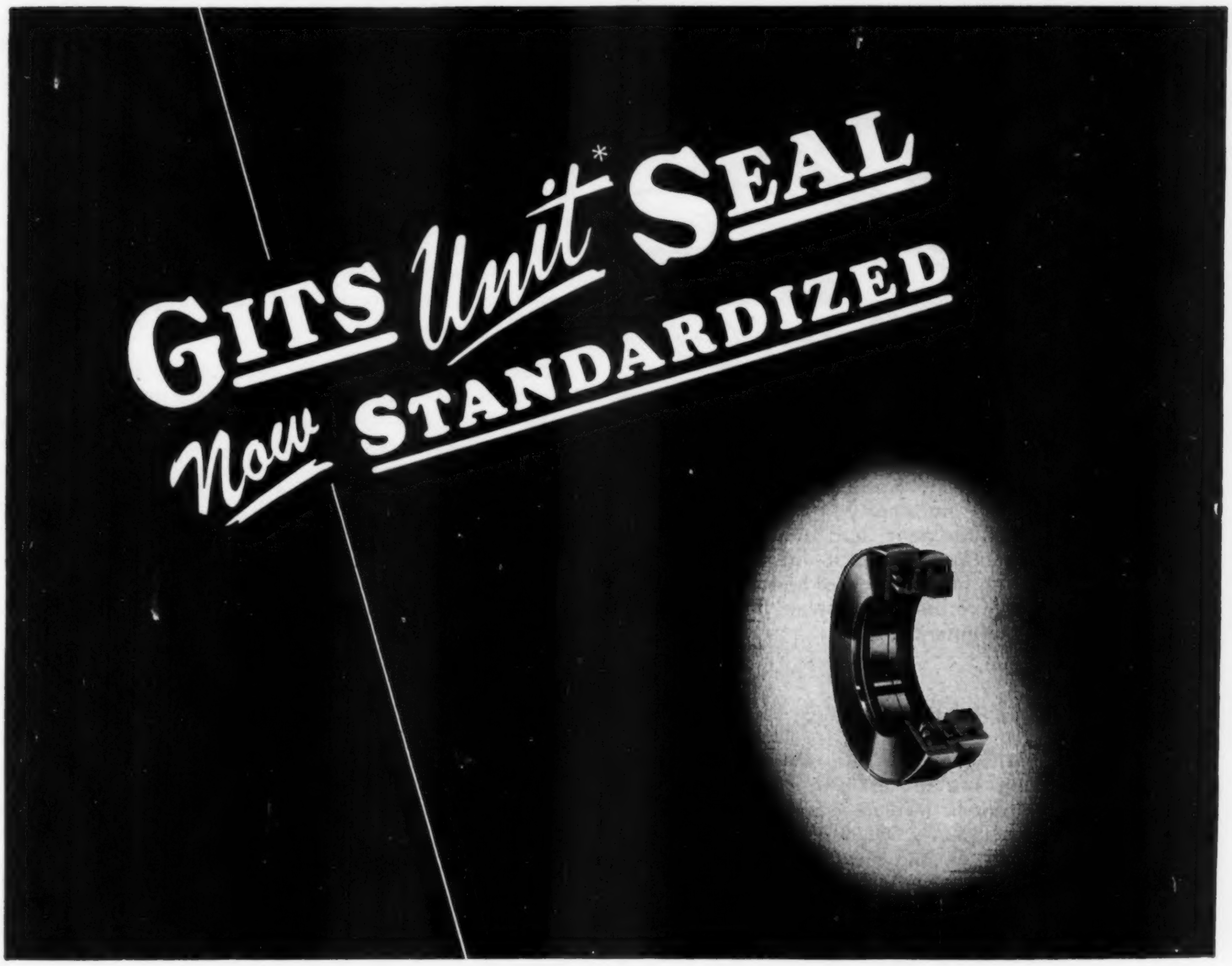
Doman Helicopters Inc., Danbury, Conn., has appointed **John W. Mazur** as chief design engineer. Recently head of the engineering section of the Rotary Wing branch of the Flight Test division at the Maryland Naval Base, he established methods of flight testing helicopters and of reducing test data for the Navy, and assisted the Navy and other agencies in preparing helicopter specifications. He also served at Hamilton Standard Propellers for six years as test engineer and later as rotary wing design engineer.

•

Cleveland Valve Div. of the Parker Appliance Co., Cleveland, has appointed **Robert C. Dyrenforth** to the post of division engineer, with both product and process engineering responsibilities. He joined the company last year, and was formerly associated with the Swartwout Co. as assistant chief engineer.

•

P. C. Smith was recently appointed manager of the Transportation and Generator Div. of Westinghouse Electric Corp. at East Pittsburgh, Pa. Mr. Smith



For . . .

Gear Reduction Units
Aircraft Reciprocating Engines
Automotive Accessories
Jet Propulsion Units
Washing Machines
Standard & Special Machine Tools
Electrical Power Equipment
Business Machines

*Cartridge Seal . . . pressure balanced . . . requiring only 25% more space than lip-type seals.

If *you* have a shaft sealing problem, Gits experience in these and many other specific applications can prove of great and immediate value to you.

Write today for FREE illustrated Brochure, or send us your seal problem.

GITS BROS. MFG. CO.

1868 S. Kilbourn Ave. • Chicago 23, Ill.

Gits Lubricating Devices,
The Standard For Industry For Over 40 Years

joined the Westinghouse graduate student training course at East Pittsburgh and later attended the company's engineering and design schools. In 1929 he was appointed design engineer of induction motors for the Transportation and Generator Div. and became assistant to the manager of that division in 1944. In June of last year Mr. Smith received the Westinghouse Order of Merit "for his proficiency in designing large motors for special and difficult applications. . ."

♦

Nathaniel K. Zelazo has been appointed vice president of Ketay Mfg. Corp. of New York and Hawthorne, Calif. He will help direct expanded operations in the company's field of automatic control system development and manufacture for government and industry. Mr. Zelazo was formerly with the Department of Defense, Electronics Production Resources Agency. Working with the Bureau of Ships and the Bureau of Aeronautics, he pioneered in the research and development of miniaturized electronic components, fire control radar systems and airborne control systems.

♦

A specialist in the computation, design and development of fractional-horsepower motors, **Jack Miller** recently joined the engineering staff of Holtzer-Cabot, division of National Pneumatic Co. Inc., Boston. Dr. Miller was educated and worked for a number of years in Europe.

♦

R. H. Zeilman was recently named director of engineering at Thew Shovel Co., Lorain, O.; **M. L. Sheetz** was appointed chief executive engineer; and **O. Von Mehren** was named chief design engineer. At the same time **E. C. Brekelbaum,** former vice president and executive engineer of Harnischfeger Corp., was named to the newly created post of director of methods.

♦

Chain Belt Co., Milwaukee, recently appointed **Bernhard G. Schneider** to the newly created post of assistant chief engineer, conveyor equipment section, of the Conveyor and Process Equipment Div. Mr. Schneider joined the company in 1926 and has since served in various technical and supervisory capacities.

♦

Arthur F. Erwin and **Edward F. Brill** have been appointed manager and chief engineer, respectively, of the atomic power section of Allis-Chalmers Mfg. Co., Milwaukee. Mr. Erwin joined the company in 1935, completed the graduate training course and was named an assistant engineer in the engine and condenser department. In 1943 he was appointed secretary of the development committee and in 1951, assistant manager of the atomic power section. Associated with Allis-Chalmers since 1941, Mr. Brill spent 21 months as a graduate training student in various sections of the electrical department. He has been engaged in development engineering work since 1943. He transferred to the atomic power section in 1949 and three years later was named engineer-in-charge.

THE ENGINEER'S

Library

Recent Books

Fatigue and Fracture of Metals. *Edited by William M. Murray, associate professor of mechanical engineering, Massachusetts Institute of Technology;* 321 *pages,* 6 *by* 9 *inches, clothbound; published jointly by The Technology Press of the Massachusetts Institute of Technology and John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $6.00 *postpaid.*

Fourteen papers, presented at a special summer conference on the Fatigue and Fracture of Metals at the Massachusetts Institute of Technology in June of 1950, make up the contents of this book. Purpose of the volume, as stated by J. C. Hunsaker in the foreword, is "that this publication will, as a survey of existing knowledge and expert opinion, contribute usefully to the improvement of our control of the basic elements involved in the problem of fatigue and fracture." Subjects treated include a general survey of the problem; fatigue in aircraft; brittle fracture and fatigue in ships and machinery; internal stresses and fatigue; designing for fatigue; brittle behavior in metals; statistical aspects; cumulative damage in fatigue; significance of transition temperature; influence of metallographic structure; fatigue at high temperatures; and techniques for studying damage.

•

Mechanics. *By J. L. Meriam, associate professor of engineering design, University of California; Part* 1—*Statics,* 352 *pages; Part* 2—*Dynamics,* 345 *pages;* 6 *by* 9 *inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, *postpaid; Part* 1, $4.00, *Part* 2, $4.00.

Engineering or applied mechanics is the subject of this basic text which has been made up in two volumes—statics and dynamics. Fundamental principles have been emphasized, particularly with respect to their application to practical problem solutions. Selection of problems, which have been graded according to difficulty, has been based on actual situations rather than idealized conditions. Both text material and problems are well illustrated. Part 1, Statics, deals with principles of mechanics, force systems, equilibrium, structures, distributed forces, beams, friction and virtual work. Part 2, Dynamics, begins by repeating the first chapter of Part 1 on principles of mechanics and goes on to treat kinematics, kinetics, acceleration, work, energy, impulse, momentum and periodic motion. Concluding portions of both books have appendix sections which cover

moments of inertia of areas and masses and useful tables.

•

Textbook of Engineering Materials. *By Melvin Nord, associate professor of chemical engineering, Wayne University; 528 pages, 6 by 9 inches, clothbound; published by John Wiley & Sons Inc., New York; available from* MACHINE DESIGN, $6.50 *postpaid.*

Basic engineering concepts of the properties of raw materials and their manufacture into engineering materials are discussed in the first half of this book which is designed primarily for engineering students. The second half deals with the problems of uses and production as applied to specific materials

Manufacturers' Publications

Weldability of Metals. 141 *pages,* 5½ *by* 8½ *inches, paperbound; available from the Lincoln Electric Co.,* 22801 *St. Clair Ave., Cleveland* 17, *O.,* 50 *cents postpaid.*

Reprinted from the *Procedure Handbook of Arc Welding Design and Practice,* this booklet deals with the welding of ferrous and nonferrous metals. Factors determining weldability; causes and cures for hard to weld metals; and welding procedures for steels, nickel, iron, alloys, copper, aluminum and hardfacing are explained.

New Standards

Track Bolts and Nuts. *ASA B*18.10-1952; 9 *pages,* 8½ *by* 11 *inches, paperbound; copies available from American Society of Mechanical Engineers,* 29 *W.* 39*th St., New York* 18, *N. Y.;* $1.00 *a copy.*

Track bolts and nuts used by the various railroads and electric railways in the United States and Canada are covered. Recommended dimensions are based on existing conditions and usage, and simplification of manufacture.

•

NEMA Standards for Electrical Insulating Varnishes. *Publication No. IV* 1-1952; 24 *pages,* 8½ *by* 11 *inches, stiff-paper cover; available from National Electrical Manufacturers Association,* 155 *E.* 44*th St., New York* 17, *N. Y.;* $2.50.

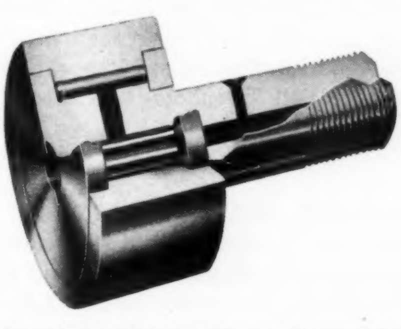
The first publication by NEMA on the subject of electrical insulating varnishes, this standard contains information concerning the specific gravity, viscosity, drying time, nonvolatile content, oilproofness and dielectric strength of spirit soluble, oxidizing air drying, thermosetting, oxidizing baking and asphaltic types of varnish.

CAM ACTION IMPROVED with MULTIROL® BEARINGS

under heavier loads • with shock resistance • and space economy

Modern demands for faster, more automatic machines necessitate a new approach to cam action efficiency. Improvised bolt and roller units are no longer adequate for this mass production machine age.

Machinery manufacturers are finding that even at slow speed, it is difficult to carry the usual heavy radial and intermittent shock loads of cam application efficiently on plain bearings or standard anti-friction ball and roller bearings. With increasing speeds, and lubrication limited by the desire for simplified design, the plain bearing wears excessively and fails early. Ordinary ball or radial roller bearings used on a shaft as cam followers have a



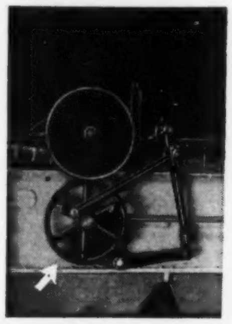
tendency to split in the outer race because of the excessive strain on the thin and superhard race sections.

One bearing that has proven particularly successful in cam follower applications is the Multirol CF series full type roller bearing. This bearing is built especially for the repeated shock loads of typical cam action operations. The outer race section is not only heavy radiclly but is also martempered to combine maximum toughness with adequate surface hardness for withstanding the punishment of cam applications. The outer ring operates on a full complement of small diameter rollers so the load is evenly distributed over a greater bearing surface. The inner race and flange are made in a single piece with the stud, preventing any possibility of disassembly in operation. Greater accuracy is maintained throughout longer bearing life and, compared with plain bearings, both starting and rolling friction are reduced to a minimum. As a result internal wear is diminished and power requirements of Multirol bearing equipped machines are appreciably lessened.

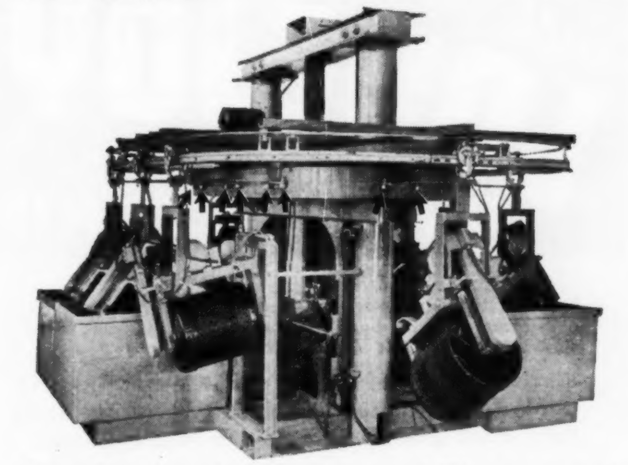
Load Capacity Comparison

To illustrate the increased capacity of the Multirol CF, here is a comparison between a Multirol CF-1 bearing and a corresponding friction type roller, making use of the maximum permissable bearing pressures in pounds per square inch of projected area. The CF-1 bearing will have a maximum of 2240# while the equivalent friction type roller would have a capacity of less than 400#.

What This Means in Terms of Performance

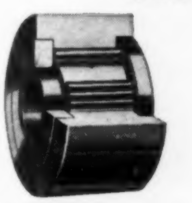


The James Hunter Machine Co., of North Adams, Massachusetts replaced units consisting of a standard roller bearing and hardened roller with Multirol CF bearings on eccentric cams that actuate rake teeth in their wool washers. The changeover reduced their original and replacement costs over 10% and reduced maintenance to occasional lubrication. Where previously, rollers only lasted a maximum of several months, no replacements have been required with the Multirol bearings. As a result, the Multirol Bearings solved a trouble spot that brought in many customer complaints.

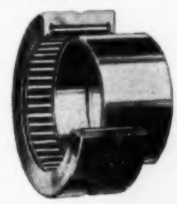


Crown Rheostat and Supply Company of Chicago uses up to 200 Multirol Cam Followers as guide and support rollers in the travel and transfer mechanism of their cleaning, plating, and drying machines. Formerly trolleys were suspended from rails but the cam follower units proved to be a more precision means of friction reduction and added stability to the supporting arms.

Other McGILL® Bearings



MULTIROL CYR



MULTIROL SE

GUIDEROL CT

A new 140-page Bearing Reference Guide complete with 30 pages of vital engineering data has just been released by the McGill Manufacturing Company. It has the full story on the advantages of Multirol CF Bearings as well as information on the Multirol CYR, Multirol SE and Guiderol Bearings. Send now for your copy of McGill Catalog No. 52.

McGILL® — Precision Bearings

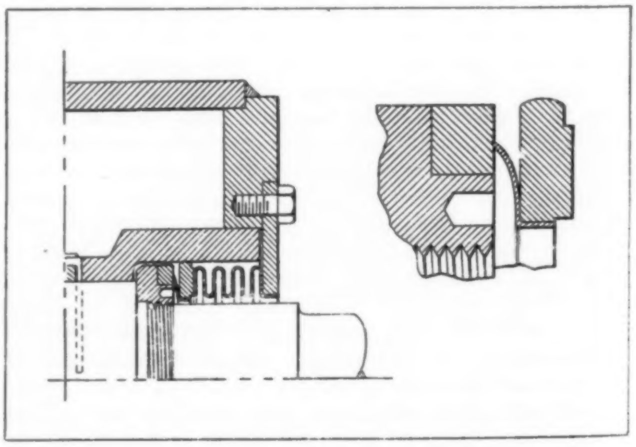
McGILL MANUFACTURING COMPANY, INC.
200 N. Lafayette Street, Valparaiso, Indiana

NOTEWORTHY

Patents

SUBMINIATURE BALL BEARINGS employing dehydrogenated carbon balls in their design are covered by patent 2,609,256. Invented by William O. Baker and Field H. Winslow, the bearings are suitable for watches and other delicate instruments with small rotating parts. The balls are made by a special polymerization process which produces perfect carbon spheres in diameters from 0.01 to 1-millimeter—a size range not feasible with conventional ball production methods. Hardness of the balls approaches that of a diamond and the smooth surface finish attained insures minimum frictional resistance. Permanent lubrication is provided by baking a surface coating of graphitic carbon on the balls. The patent has been assigned to the Bell Telephone Laboratories.

CHATTERLESS SHAFT SEALING at speeds as high as 7000 rpm is accomplished with a bellows-actuated mechanical seal assigned to General Electric Co. by Christian Steenstrup under patent 2,610,873. Designed for use on drive shafts of high-speed externally powered units, the seal consists of a rotating hard-



surfaced metal wear ring and a stationary soft metal dished seal nose which engages the ring face on edge. Sealing pressure is maintained by the stationary spring bellows which exerts force through a guide ring attached to the soft metal nose. Construction of the seal prevents the chattering or bouncing at high speeds which would impair sealing efficiency.

PISTON RING EXPANSION is accomplished with a protected rubber O-ring in the unique assembly as-

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gives more efficient lubrication of spindles, gears, bearings, small air-operated devices.

EXCLUSIVE NORGREN FEATURES

Complete Visibility and Control of Oil Feed **. . . no guess work.**

Oil Feed Controlled by Air **. . . gives very uniform rate of oil feed.**

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The oil-fog principle of lubrication was born 25 years ago in the Norgren laboratory. Since then Norgren's continuous lubrication research has helped thousands of manufacturers improve their products —Norgren lubricators are standard components on most types of equipment where the best of lubrication is required for high speed spindles, air cylinders and valves.

The latest Norgren development is a new type Micro-Fog Lubricator, incorporating the above exclusive features, designed to give reliable, uniform lubrication of one or more high-speed spindles, bearings, gear boxes and small air-operated devices. It produces an extremely fine and uniform air-borne micro-fog at low air flow; transmits it over greater distances than previously possible; distributes it evenly through multiple outlets; provides exact control and a uniform rate of oil feed under all operating conditions.

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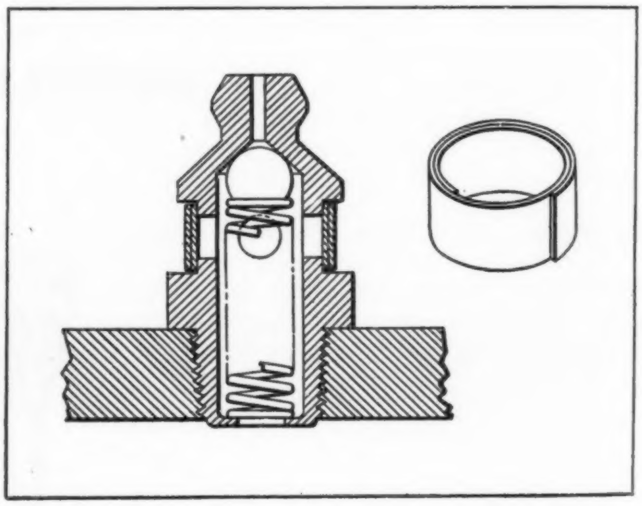
Valves • Filters • Regulators • Lubricators • Hose Assemblies

Noteworthy Patents

signed to the Auto-Diesel Piston Ring Co. under Patent 2,607,644. Invented by Rolland D. Smith, the assembly utilizes a thin flat strip of spring metal to protect the inner rubber expander from damage by the joint ends of a conventional one-piece split piston ring. Application of the expander, which fits standard ring grooves, increases useful piston ring life and resilience.

OVERLUBRICATION PROTECTION is afforded in a grease fitting for antifriction bearings assigned to General Electric Co. Described in patent 2,611,450, the fitting is essentially a modification of the standard nipple type having, in addition, recessed circumferential ports covered by a prestressed spring band. Ex-



cessive grease pressures expand the band and permit lubricant to be discharged through the ports, affording positive automatic relief and providing a visual indication of overlubrication. The fitting, which may be used with heavy or light greases, also minimizes contamination and reduces grease oxidation. Inventor of the device is Irving Kalikow.

LIMITED VIBRATION AMPLITUDE at resonant frequency, a feature of the isolator in patent 2,610,-017, prevents damage to delicate mounted equipment. An invention of Frank Lambert Jr. and Charles E. Crede, the isolator employs a volute spring enclosed by a spherelike rubber diaphragm to obtain large damping capacity. Expulsion of air, compressed by deflection, through a small opening in the diaphragm provides necessary damping action and limits amplitude at resonance. Operation of the isolator is effective at both high and low temperatures. In addition, the natural frequency of the device remains constant regardless of load, eliminating the need for predetermination of weight distribution. Assignee of the patent is the Barry Corp.

Engineering News Roundup

Wind Tunnels Require Largest Motors, Compressors

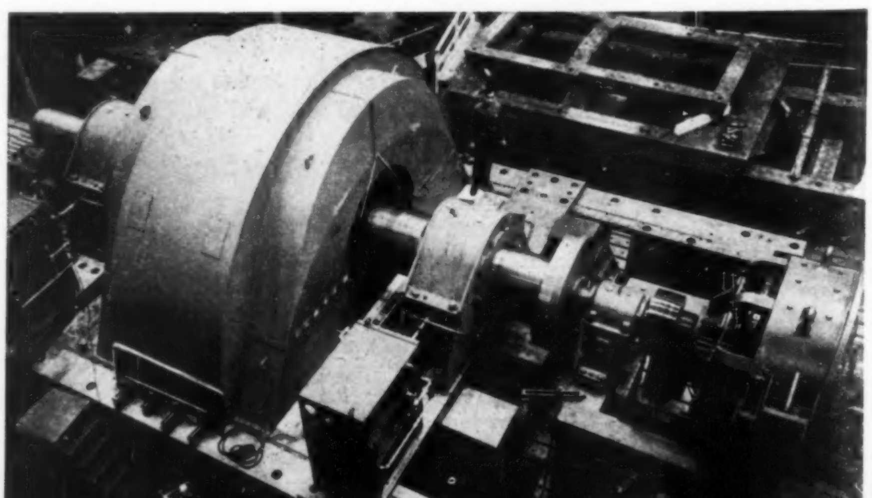
The largest rotating machine ever built is being assembled by Westinghouse, consisting of the five compressors and drive for transonic and supersonic wind tunnels being built for the U. S. Air Force at Tullahoma, Tenn. The compressors are to be driven by four motors which provide a total of 216,000 horsepower. These motors will be installed in tandem. Two of them, rated at 83,000 horsepower each, are the largest motors ever built. They stand 21½ feet high and weigh 225 tons. Their 122-ton rotors will turn at the rate of 600 revolutions per minute.

The supersonic compressor for the wind tunnel will consist of four compressors in series; the transonic compressor will be a single unit. Each inlet-stage blade is more than 2 feet across the face, 6 feet long, weighs almost 2/3 of a ton, and rotates at 600 rpm on a spindle 18 feet in diameter. Tip speed is 650 mph and centrifugal force is 800 tons. Solid forgings, the blades will be rooted to disks that are the largest that can be forged anywhere in the world.

The two liquid rheostats for motor speed control, to be used for secondary control of the two wound-rotor machines during starting, load transfer, etc., are also the world's largest.

The machine itself measures 575 feet from end to end and weighs 1000 tons. Its inertia amounts to 77 million lb-ft^2. Stored energy at a speed of 600 rpm is 2400 horsepower-hours. Although it represents the highest stored energy of any rotating mass ever built, the machine can be stopped in about three minutes by using the wound-rotor motors as brakes and transferring energy into the liquid rheostats.

Cooling the air stream is accomplished with water flowing at the rate of 100,000 gallons per minute through coolers; air discharge temperature is still above 600 F. Air in the test chamber, however, will be about −100 F.



Compressor blades for the world's largest rotating machine are as tall as a man, left. Above, one of four motors which will drive the compressors is rated at 83,000 hp

Offer Suggestions To Remedy Engineer Shortage

Industry and civilian government presently need between 40,000 and 50,000 new engineering graduates; requirements of the military services and education make the deficit even greater. Estimates on the number of engineers which colleges will produce during the next three years vary somewhat, but the number of engineers graduating will decrease by several thousand each year, while the need for graduate engineers is constantly increasing. These factors, coupled with growing military needs for engineers, threaten the output of civilian and defense production.

A three-fold program to establish the importance of engineering to the public welfare, to aid in maintaining the supply of trained engineers, and to promote the most effective utilization of engineers is being sponsored by the Engineering Manpower Commission of Engineers Joint Council for the coming year.

According to T. A. Marshall Jr., executive secretary of EMC, industry's supply of engineers can be "stretched" by relieving them of detailed duties that can be done by other personnel. One estimate of the manpower that can be saved is given by Titus G. LeClair, manager of engineering of Commonwealth Edison and Public Service Co. of Illinois, speaking at the Fifth College-Industry Conference held recently at Northwestern University, who stated that requiring an engineer to handle all the details of his job is "our greatest source of wasted engineering talent." A graduate engineer can increase his working effectiveness at least 10 or 15 per cent if he is assisted by dependable technicians, he said. Such assistants, with one or two years of college or technical institute training, could come from the ranks of scientifically inclined individuals who are not able to complete college training.

Streamlined working procedures can save a good deal of the engineer's time. At General Electric, for instance, draftsmen save from 20 to 30 per cent of the time normally required to prepare drawings by simplifying and eliminating nonessentials on drawings and layouts. Use of free-hand drawings is encouraged, as are written descriptions when drawings are not actually needed.

Practicing engineers can contribute to the cause of more effective utilization of their talents by keeping abreast of current technological developments and taking advantage of postgraduate educational opportunities. In this way specialists can grow in their profession and benefit themselves as well as industry.

Discussing problems involved in recruiting talented young persons for the engineering profession, Clarence E. Deakins, dean of students at Illinois Institute of Technology, told the College-Industry Conference that "industry itself is in direct competition with colleges for the high school graduate." Graduates with mechanical skills and interests are attracted to high-paying jobs in industry, especially if they cannot easily afford a college education. Mr. Deakins urged that engineering aptitudes be recognized early in secondary school students and that industry increase scholarship funds for talented students. Since most scholarships are made available to juniors and seniors, entering freshmen do not benefit by present programs.

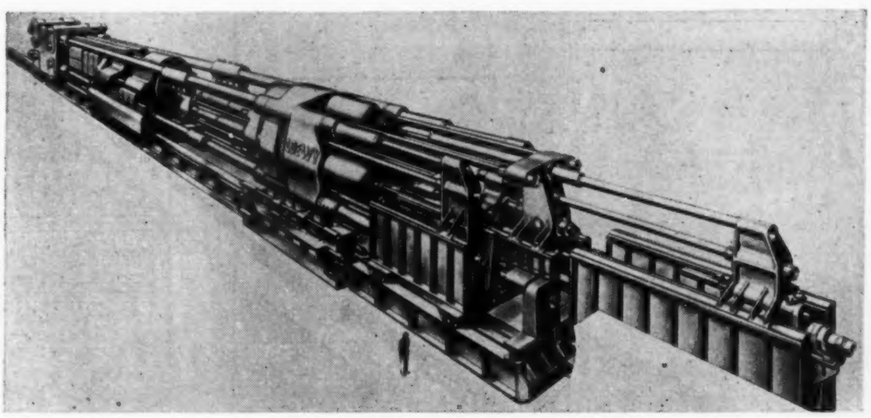
According to Mr. Marshall's EMC report, industry is anxious to employ engineers who are now terminating their military duty. These engineers are urged to contact their college placement offices, which are constantly in touch with industry.

Large Generator First to Use Liquid Cooled Conductors

The first large generator in the history of the electrical industry with liquid-cooled conductors will be manufactured by the General Electric Co., Glenn B. Warren, general manager of the Turbine Div., recently announced. To be installed at the Eastlake plant of the Cleveland Electric Illuminating Co. by the end of 1955, the unit consists of a tandem-compound turbine rated at 208,000 kilowatts and a generator rated at 260,000 kilovolt-amperes.

Liquid circulates through hollow conductors in the stator, cooling the stator assembly. Liquid cooling, Mr. Warren said, makes possible a significant increase in generator capacity without increasing physical size because of more efficient removal of heat produced during the generation of electricity. A presently used method of cooling large generators by circulating hydrogen gas through passages in the rotor and stator will be used for cooling the rotor.

A 20,000-ton extrusion press will be installed at Alcoa's Lafayette, Ind., plant as part of the government-industry heavy press program. Scheduled for completion by the middle of next year, this press will produce large extruded shapes for military and civilian aircraft. Maximum weight for extruded shapes will be $2\frac{1}{4}$ tons; maximum length for heat-treated shapes, set by existing heat-treating equipment is 90 feet. The press will be capable of extruding ingots 18 to 41 inches in diameter and nearly 8 feet in length. Peacetime uses will include the production of wide, thin shapes for building curtain-wall construction and large size pipe for the chemical and petroleum industries



Engineering News

Allocation Controls On Metals End June 30

Allocation of steel, aluminum and copper to civilian users will end on June 30, with open-ending effective immediately.

Modification of the Controlled Materials Plan, in effect since 1951, was announced recently by acting defense mobilizer Arthur S. Flemming. Between now and the midsummer date, Defense Department and atomic energy priorities will continue to be honored first. If extra supplies exist after filling these orders, they may be used by anyone for any purpose.

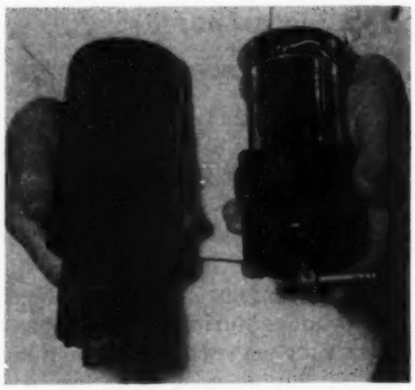
No decision had been reached at press date regarding type of controls to be instituted after June 30 to insure delivery of military and AEC requirements. The Steel Products Advisory Committee of NPA has urged that no form of controls be held, except to safeguard these requirements, at least in steel. Their recommendations include the establishment of a task force to provide procurement assistance for these two vital projects, and the establishment of production directives on steel producers and further converters to provide the necessary steel.

At the same time, the Office of Defense Mobilization pointed out, production ceilings such as those on passenger cars and trucks were ended by the action. Allocations of steel have previously restricted production but, after the needs of all present ticketholders are honored, manufacturers may produce as much as they want if they can obtain the steel.

The situation is not as clear in copper and aluminum. Both have been in tight supply, and allocation controls may have to be retained beyond the June 30 deadline. Brass and bronze foundry advisors to NPA have urged retention of controls over copper beyond this date. The advisors have also recommended immediate removal of price controls on refined copper and copper-base alloy scrap.

Automatic Control "Reads" Instruments

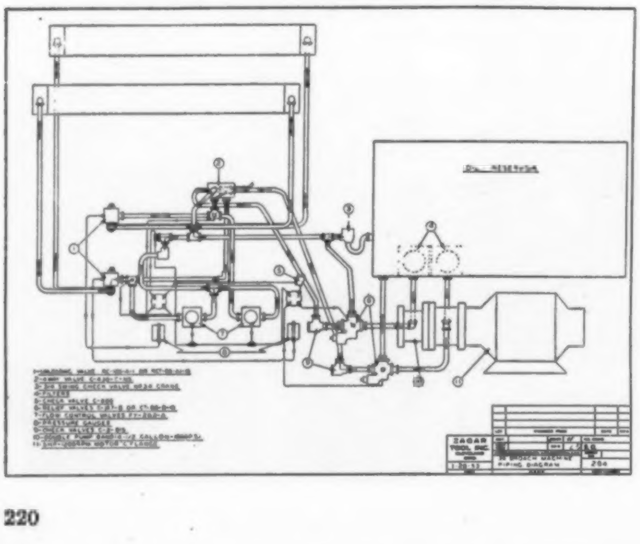
A new control, for use with rotating pointer instruments, watches the pointer, and initiates corrective action if the instrument deviates from the correct value. Contained in a case 4 inches long and 3 inches in diameter, the control is made for mounting directly on the face of instruments now in use. Developed by laboratory analysts Win Alderson and Douglas Erickson of the Ryan Aeronautical Co., San Diego, Calif., to automatically maintain speed, altitude or direction of uninhabited missiles or aircraft, it could also be used to maintain temperature, pressure or humidity within close limits.

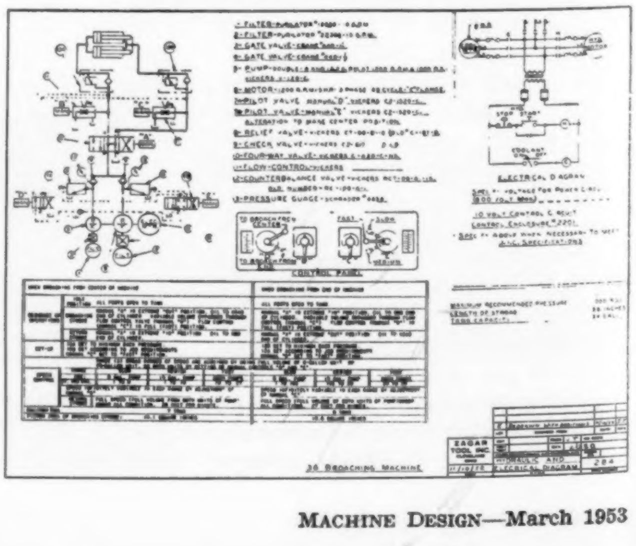


Sensitive control, developed by Ryan Aeronautical Co., San Diego, Calif., applied to an aircraft tachometer (left) and an air-speed indicator

The control case contains two tiny electric lamps, immediately adjacent to each other, a photoelectric cell, vacuum-tube amplifier and sensitive relay. A metal shield in front of the lamps has a small window through which light from the lamps can pass to impinge on the photocell. A small counterbalanced flag which replaces the instrument pointer interrupts the beam from one lamp or the other as it rotates to institute the desired action. Flag size and lamp

Contrast between lack of information on many working" hydraulic-circuit diagrams and complete data given by JIC symbols is clearly demonstrated in these two drawings. Hydraulic circuits for a 36-inch broaching machine made by the Zagar Tool Co. of Cleveland are shown in both. The original drawing, below left, was made before the inception of JIC hydraulic standards. When using this diagram, it was necessary to refer to valve catalogs to understand the workings of the valves. Using JIC Symbols, the revised diagram, below right, shows actual functioning of each valve. An electrical JIC diagram is also included so that the entire operation of the machine is explained





Farval Announces DC 20 Automatic Pumping Unit

for complete lubrication of smaller machines

FARVAL—*Studies in Centralized Lubrication*
No. 139

ALL PARTS OF THIS NEW FARVAL DC20 ***automatic pumping unit are assembled on a single base plate ready for quick, easy mounting at any convenient point. Supply lines run from the pumping station to the Dualine measuring valve manifolds, one valve for each bearing to be lubricated. The entire system is installed very simply and at a cost that will be repaid in a few months in savings effected.***

NOW any small machine can have a completely automatic system of Farval centralized lubrication—as efficient and economical as the larger systems which have proved so valuable on heavy industrial equipment during the past 26 years.

Chief component of this smaller, low cost system is the new Farval DC20 pumping unit which handles either grease or oil. In addition to the pumping unit, the complete Farval system consists of two main supply lines, the familiar Dualine measuring valves and discharge line connections from measuring valves to the bearings.

Easily installed at any convenient place on or near a machine, the DC20 insures automatic delivery of lubricant to bearings, as often as needed, in whatever quantities desired, while the machine is in operation. Remember that Farval—and Farval only—employs the Dualine valve that is fully adjustable—simple, sure and foolproof—with a positive indicator which visually signals that the valve has functioned.

Hundreds of operators using the larger Farval automatic systems have discovered that the entire cost of a system is saved the first year. Lubricant savings alone may run as high as 75%.

Investigate the new DC20. Near you is an experienced Farval lubrication engineer who will demonstrate how the new DC20 pumping unit can save time and money and increase production on your present hand-lubricated machines. Write today for a copy of Bulletin 39, "DC20 Pumping Unit for Smaller Machines". The Farval Corporation, 3265 East 80th Street, Cleveland 4, Ohio.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

FARVAL
CENTRALIZED SYSTEMS OF LUBRICATION

spacing determine the operating differential of the control. Response to a pressure change of 0.1-inch of water is possible.

Laboratory tests have shown that accuracy of the device changes less than 0.1-per cent over a temperature range of 189 F. Vibration of 55 cycles per second at 0.030-inch amplitude produced less than 2 per cent error. In addition to being rugged, inexpensive and accurate it does not require a high-voltage power supply but operates on 24 volts dc.

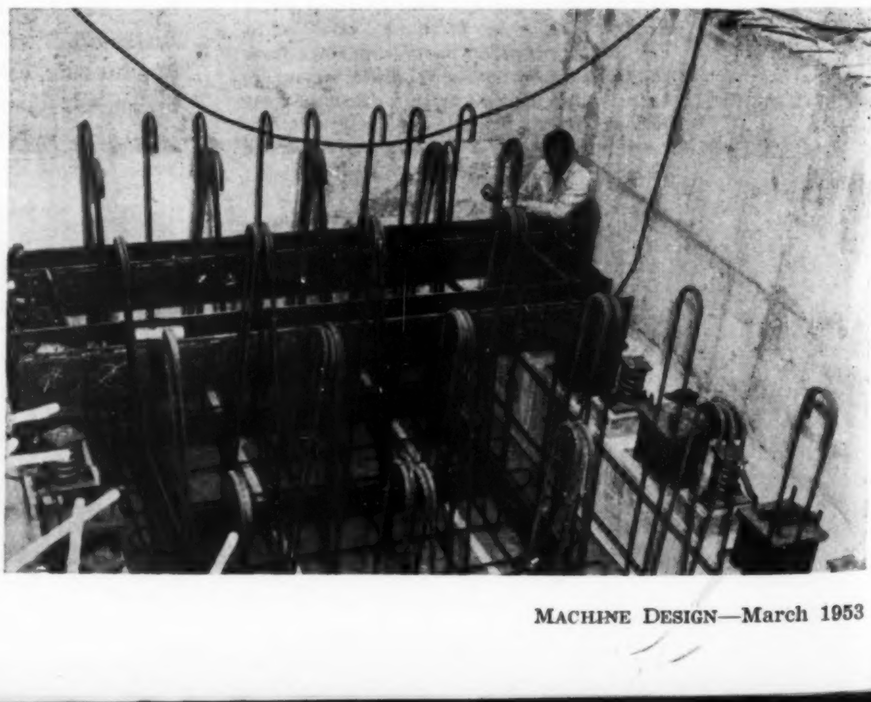
Hammer Blows Cushioned by Coiled Springs and Concrete

Concrete "floating" islands weighing as much as 138,000 pounds are cushioned upon sets of coiled steel springs to absorb the shock from two Cecostamp forging hammers. Designed by the Ryan Aeronautical Co. engineering department, these foundations eliminate vibration caused by operation of the hammers. Reinforced concrete masses float in pits approximately 10 feet deep, 16 feet wide and 22 feet long, momentarily absorbing the force of the hammer blows.

As much as 106,000 pounds of force are exerted by the hammers in forming stainless steel exhaust systems and jet engine parts. The springs upon which the concrete blocks are suspended are made of cold-rolled crucible steel and can absorb a force of 2800 pounds per inch of deflection.

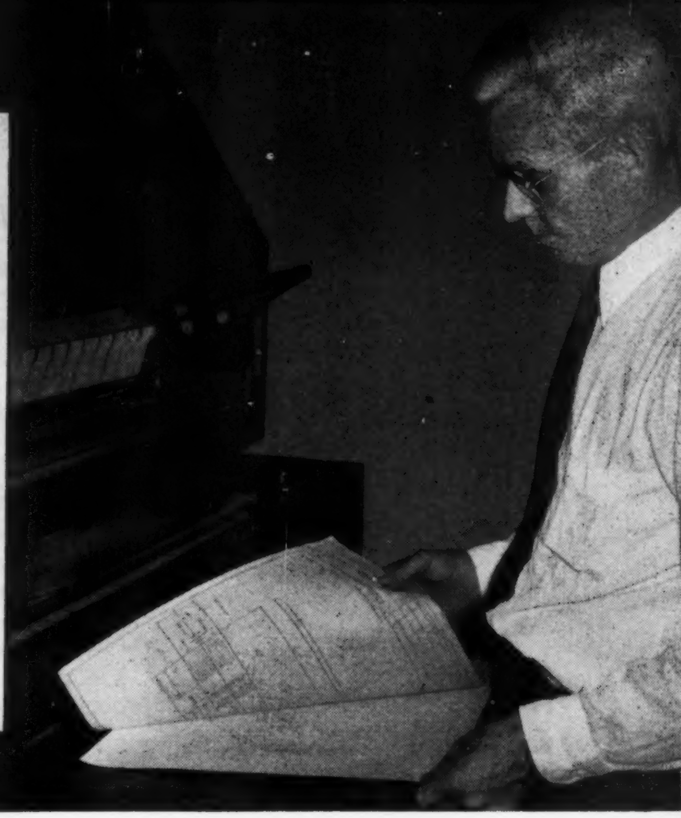
In operation, the inertia blocks receive the impact of the hammers, and depress the supporting springs ⅜-inch per blow. The foundations oscillate until the energy is dissipated through friction. An advantage claimed for this floating foundation method of machine mounting is the facility of keeping the machines in plumb. Adjustable leveling jacks are located at each spring mounting.

One of the largest blast furnace turbo-blowers ever built in this country is a five-stage unit with a rated capacity to deliver 121,000 cfm of air at 35 psig discharge pressure. It will be driven by a 15,200-horsepower, 2500 rpm 16-stage De Laval steam turbine under operating steam conditions of 400 psi, 750 F with 28-inch vacuum. Total weight of the blower and turbine is over 167 tons; the blower unit accounts for more than 106 tons of this weight. Blower casing has 12-ft OD



Important savings at Eureka-Williams Corp. because

ALL drawings are reproduced on Kodagraph Autopositive Paper



Positive photographic intermediates are produced *directly,* without the negative step. A standard print-making machine is used for exposure; standard photographic solutions for processing. A fast, easy room-light operation *that saves time and money!*

In print production . . . no wear-and-tear to valuable originals. The Eureka-Williams Corp., Bloomington, Ill., protects its ever-growing investment in drafting time and dollars by using low-cost Kodagraph Autopositive intermediates to obtain the desired number of shop prints. These intermediates, unlike the original drawings, will not smudge or lose line density with repeated printings . . . will produce highly legible prints time after time. Furthermore, their dense photographic black lines and evenly translucent base permit running the prints at uniform, practical speeds. *Which adds to the convenience—and the economy.*

In drafting . . . revisions made 7 times faster. The basic designs for Eureka-Williams oil burners, furnaces, and vacuum cleaners are being modified constantly for the production of various models. Here's just one way Autopositive is used to boil 3 days of drafting time down to 3 hours—

1. An Autopositive intermediate is made of the drawing which is to be revised.
2. The draftsman deletes the unwanted parts of this print with a razor blade.
3. From this, another Autopositive intermediate is made.
4. Then the draftsman only has to add the new design . . . and a new "file original" is ready. From it, additional Autopositives can be made for print production.

Costs are also cut by making Autopositives of office records, and other non-translucent records which are unsuitable for use as print-making masters.

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TRADE-MARK

Engineering News

Last Allocation Control Revoked for Chemicals

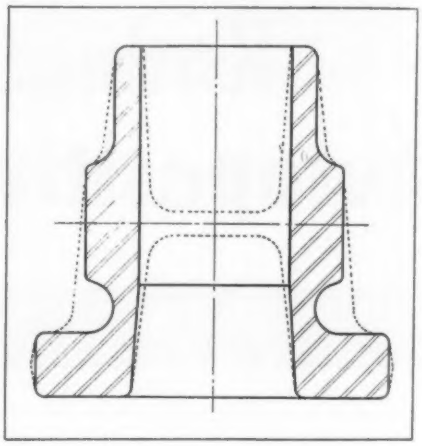
The basic control order governing the allocation of chemicals, plastics, rubber and allied products was revoked recently. Revocation of Order M-45 followed the elimination of allocation controls on Thiokol, the last such order in existence in the chemical field.

In announcing the change, the National Production Authority stated that supplies of Thiokol have now been balanced with civilian and military needs. Thiokol is an elastomer having none of the chemical properties of natural or synthetic rubber. It is used in military machines for various purposes, including the sealing of joints in aircraft, and is less sensitive to extremes of temperature than either type of rubber.

New Forging Method for Steel

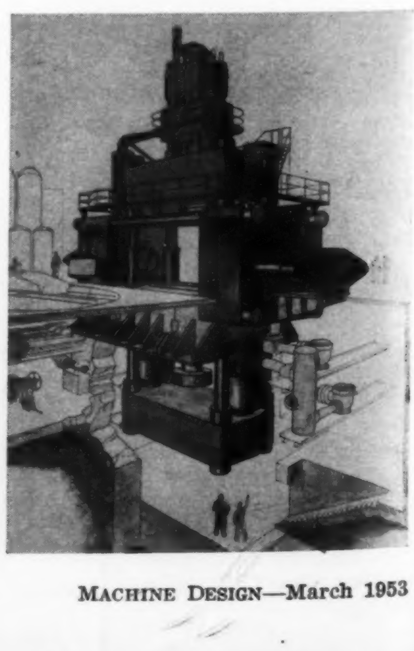
A closed-die press in use at the Cameron Iron Works Inc., Houston, Tex., forges steel parts formerly made by casting. The press, built by the A. B. Farquhar Co., has a capacity of 5000 tons on the vertical ram and 2000 tons on each of the horizontal rams. Ordinarily, the horizontal rams hold the split dies while the vertical ram displaces metal in the split dies and pierces the billet. However, the vertical ram may be used to hold the dies closed while the horizontal rams pierce or displace metal. Forgings to 1900 pounds in weight are being successfully made of AISI-4132 steel by this process. Type 410 stainless steel has also been used.

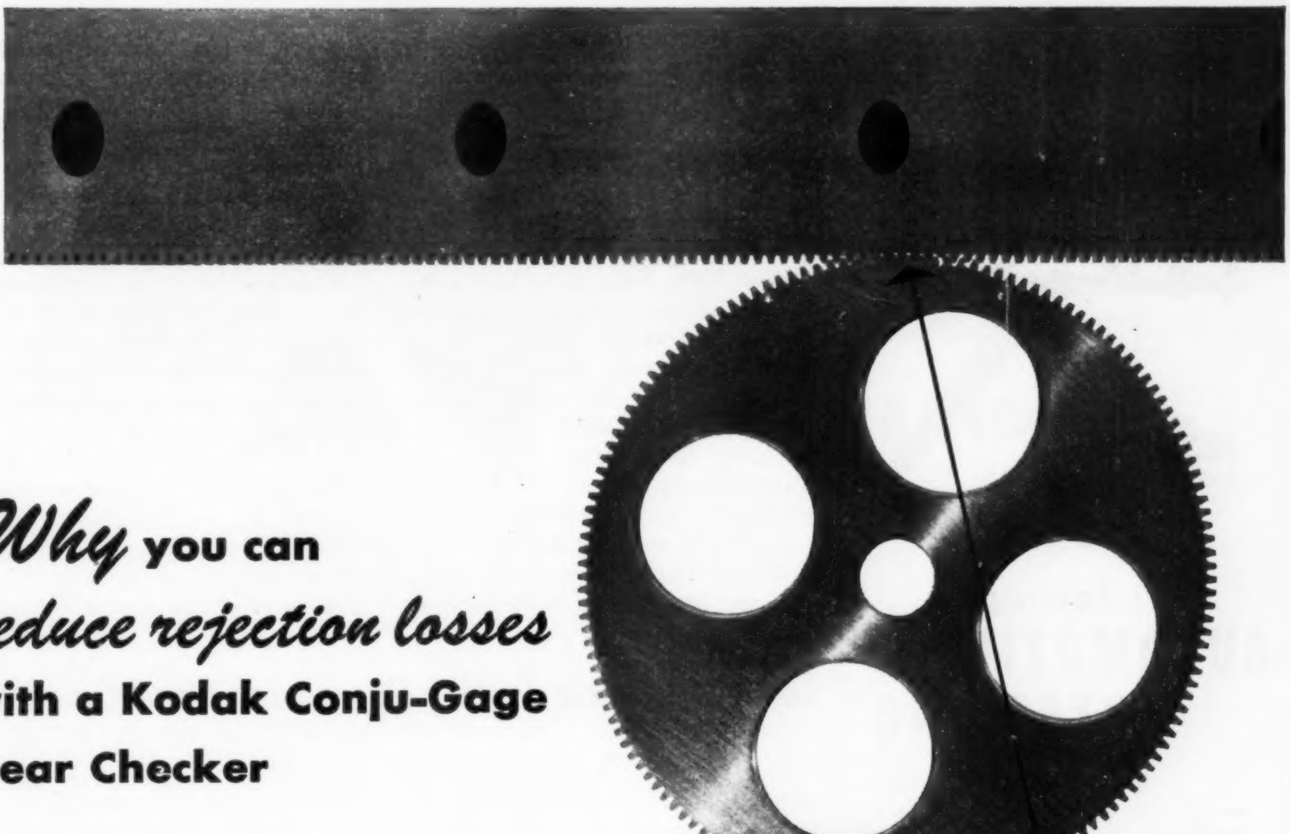
Press-forgings produced in split dies need practically no draft; therefore, little machining is required to produce the finished product. An accompanying illustration contrasts a press-forged casing head (solid lines) with the same design made by hammer-forging (dotted lines). Note the amount of metal which must be removed from the hammer forging.



Application of these forging techniques to ordnance and aircraft components produced such savings that a new and larger press, below, is being built by the Baldwin-Lima-Hamilton Corp. The new press will be rated at 11,000 tons capacity on the vertical and 6000 tons on each of the horizontal rams. An inner vertical ram will permit billets to be pierced both vertically and horizontally while the vertical ram holds the split die in position.

Split dies of two-way forging press open to show the hot forging





Why you can *reduce rejection losses* with a Kodak Conju-Gage Gear Checker

Why the composite check

In practice, the final test of gear quality is how the gear works in use. The composite check recommended in American Standard B6.11-1951 shows this conclusively by measuring displacement of the gear when run against a master of known accuracy. And it does it in one quick operation that checks combinations of as many as six types of errors.

Why the Conju-Gage Gear Checker

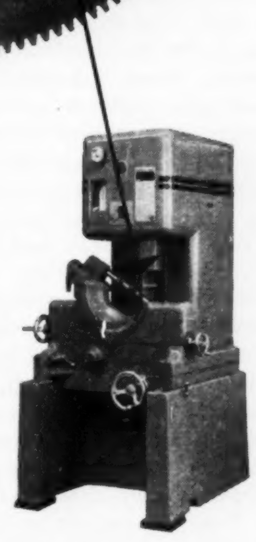
Since displacement represents the sum of both gear error and error in the master, the accuracy of the master used determines the precision of the composite check. The Kodak Conju-Gage Gear Checker uses a master of exceptional accuracy, the Conju-Gage Worm Section. Produced by thread grinding, its accuracy is not limited by the same manufacturing processes which limit accuracy in the gear itself.

To settle for masters of lesser accuracy is to rob yourself of "tenths"—to chance that tolerable error in a gear may coincide with error in the master to cause a needless rejection. Or that intolerable error in a gear may be cancelled by error in the master to pass a gear that will fail in use.

To reject every wrong gear is to guard the quality of your product. To pass every right gear is to reduce such rejection losses to a minimum.

To find out more about how a Kodak Conju-Gage Gear Checker can lower costs while maintaining required precision, send for your copy of the booklet, "Kodak Conju-Gage Gear Testing Principle." Write to

Industrial Optical Division
EASTMAN KODAK COMPANY, Rochester 4, N. Y.



The Kodak Conju-Gage Gear Checker automatically records the composite effects of runout, base pitch error, tooth thickness variations, profile error, lead error, and lateral runout. Illustrated is the Kodak Conju-Gage Gear Checker, Model 8U, for gears up to 8¼" pitch diameter. Smaller models are also available.

CONJU-GAGE INSTRUMENTATION

. . . a new way to check gear precision in action

To inspect all kinds of complex parts on a bright screen, Kodak also makes two highly versatile contour projectors.

Kodak

Engineering News

Magnesium Castings Can Now Be Shell Molded

A practical method of casting magnesium by the shell mold process has been developed. Due to its high chemical activity, molten magnesium reacts with oxygen, moisture and sand. Hence the shell molding process could not be used with magnesium until "inhibitors" to keep the molten magnesium from reacting with air and with the shell mold were developed.

Scientists working for the Army Ordnance Corps have investigated the use of various materials as inhibitors and discovered that certain materials used as inhibitors allow successful shell molding of magnesium. Plastic materials and mixing procedures which produce molds easily removable from the finished castings were also investigated.

A report of their findings and a discussion of the metallurgical properties of castings made by the processes evolved are contained in *The Application of Shell Molding to the Production of Magnesium Castings,* obtainable from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Orders should be accompanied by check or money order for \$0.75 payable to the Treasurer of the United States.

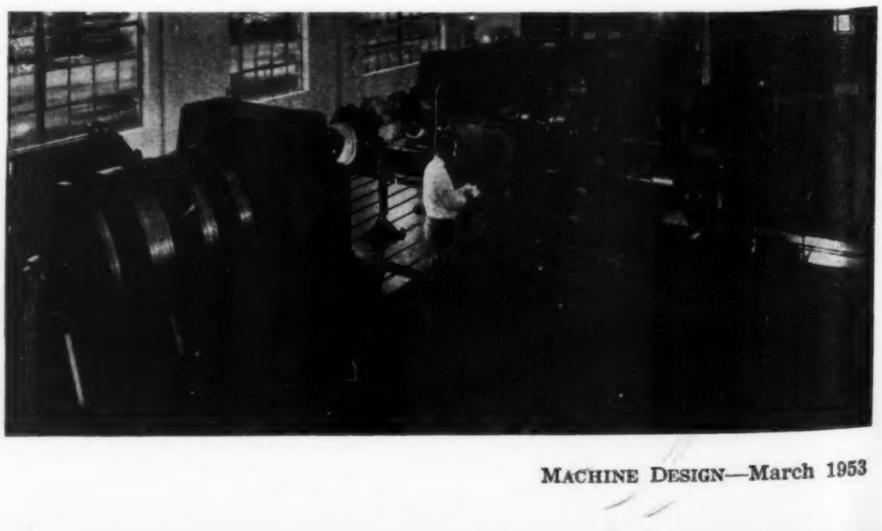
Laboratory Axle Testing Reproduces Road Conditions

The Alden Indoor Proving Ground, incorporating a method of testing axles which virtually eliminates human failure and permits around-the-clock testing without interference from weather or other conditions, is now in operation at the Timken-Detroit Axle Co. New testing equipment designed and built by General Electric is capable of simulating actual driving conditions of a truck weighing 80,000 pounds and traveling at 60 mph.

The largest dynamometers ever used for the purpose, and intricate electronic equipment for control, are used in this machine, which imposes axle tests heretofore impossible indoors. Life tests, endurance runs and shock-loading tests have been performed.

An observer rides a vehicle over a specified course which has been studied previously, making notes concerning the grades, speeds and other factors. In the indoor proving ground, an operator sitting at the test console sets the dynamometers in action and, using the manual control, records the road conditions on a magnetic tape. After the tape has been completed, automatic cycling equipment can repeat the test indefinitely. The tape reverses automatically so that the test continues without interruption.

As each stress in the test is imposed on the axle, recording instruments indicate continuously the speed, torque or load and provide a permanent record of performance. Accurate repetition of the test makes possible the establishment of the durability or life expectancy of the axle, and the recording tape can be filed so that the test can be repeated upon another or the same axle at a later date.



use TORRINGTON

Heavy Duty Needle Bearings

for maximum performance

Outstanding service over the years has won for TORRINGTON Heavy Duty Needle Bearings the confidence of machinery builders and users in every major industry.

Today you will find these rugged TORRINGTON Bearings giving free-rolling, low-maintenance service in equipment ranging from traveling cranes to rolling mills, oil well pumping units to machine tools, printing presses to auxiliary paper-machine equipment.

6 reasons why TORRINGTON *Heavy Duty* Needle Bearings will serve you better...

1 The one-piece outer race and inner race are manufactured from carburizing-grade nickel steel. Harder surfaces offer better resistance to wear; tough cores stand up under shock.

2 Their accurately ground raceway and side flange surfaces eliminate drag at the point of roller contact. Rollers operate in a true path.

3 The stainless steel retaining bands are spot welded into position. They give positive roller retention and form an internal lubricant reservoir while resisting the entry of foreign matter to the rolling elements.

4 The lubrication groove in the outer race and oil holes in both inner and outer races permit easy, effective lubrication from a drilled hole in the housing.

5 The large-fillet trunnion ends increase roller strength and present to the ground, well-lubricated side flanges a larger, more wear-resistant area.

6 Full complement of rollers assures maximum load carrying capacity.

Specify TORRINGTON Heavy Duty Needle Bearings!

THE TORRINGTON COMPANY

South Bend 21, Ind. • Torrington, Conn.

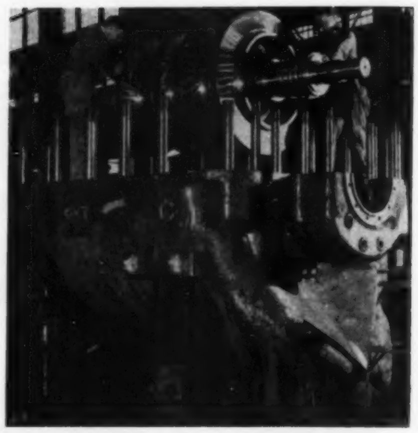
TORRINGTON *HEAVY DUTY NEEDLE* **BEARINGS**

Spherical Roller • Needle • Tapered Roller • Straight Roller • Ball • Needle Rollers

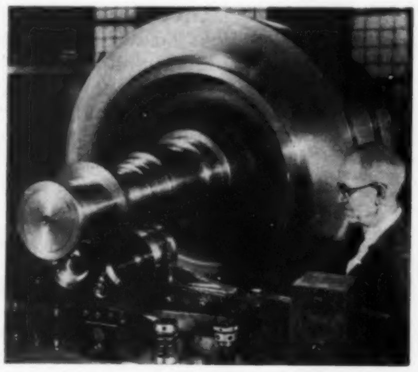
Engineering News

Build Largest Centrifugal Compressors

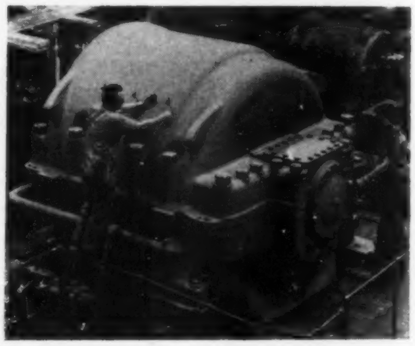
The largest multistage centrifugal compressors ever built for discharge pressures of 100 psi will be used as the main air compressors on four huge new cat crackers which are now under construction. Built by Clark Bros. Co., the compressors have a rated capacity to 100,000 cfm and will be driven by steam turbines of approximately 8000 bhp. Each compressor weighs 70 tons overall.



Rotor is positioned in lower case of compressor. Before assembly of the rotor, individual impellers were given a 15 per cent overspeed run as a final check



Assembled rotor, being driven by an electric motor, receives a final dynamic balance. Before assembly, individual impellers of the four-impeller rotor were statically balanced. Rollers which support the rotor are spring mounted, allowing the rotor to move if out of balance



Completed compressor on test stand will be driven under load by a radial expansion turbine which obtains its power by expanding the hot gases delivered to it by a power gas generator. Test thermocouples are installed to check interstage temperatures

Distribution of Research Dollar Shown by Survey

Results of a survey on industrial research and development in 1951, recently released by the Departments of Defense and Labor, show that the aircraft, chemical and electrical machinery industries accounted for 55 per cent of the money spent. Companies responding to the survey accounted for almost $2 billion of research.

Almost half of industry's research was financed by the Federal government, principally the Department of Defense and the Atomic Energy Commission. The proportion of cost borne by the Federal government varied widely by industry. Slightly more than one-third of the research cost of small companies employing less than five professional research workers was on government work while 56 per cent of the research cost of companies employing research staffs of 500 or more was for government work.

Approximately 94,000 research engineers and scientists were employed in January 1952 by the firms replying to the survey. These engineers and scientists were supported by approximately 140,000 technicians, administrative and maintenance personnel. The total cost of research during 1951 amounted to two per cent of the total value of sales and services of the responding companies, an average cost per research engineer or scientist of $22,100. Average cost of $16,500 for the chemical industry was the lowest while the motor-

vehicle industry's $68,600 was the highest. Small companies with less than five research workers had an average cost per worker of $15,400 while companies with more than 1000 on their research staffs averaged $25,000 per professional worker.

Copies of *Industrial Research and Development: A Preliminary Report* are available from Research and Development Board, Department of Defense, Washington 25, D. C.

Recommend Dropping of Copper Price Controls

Members of several industry advisory committees of NPA have recommended that price controls on copper and copper-base products be removed immediately, feeling that such a move would increase supplies of the relatively scarce material.

Scrap dealers have been awaiting the end of price controls on April 30, members of the brass and bronze foundry advisory committee say, and decontrol of prices at this point would release needed scrap for use. Ingot producers agree. Some felt that allocation controls should be retained for 30 to 60 days after price controls are removed to provide a "cushion" during which effect of the price decontrol could be studied.

One effect of price decontrol would be to give usable supplies of copper a "lift." Present ceiling is 24.5 cents, compared with a world price of 33 to 36 cents. Domestic copper users now get about 60 per cent of their metal at the lower price and the other 40 per cent at the world figure. Decontrol would probably have the effect of averaging both prices at 29 to 30 cents a pound, and would undoubtedly allow copper users to compete more effectively in the world market.

♦

Arwood Precision Casting Corp., Brooklyn, N. Y., has announced that William O. Sweeney has joined the organization as assistant vice president of sales. He was formerly sales and development manager of the Haynes Stellite Div. of Union Carbide and Carbon Corp.

Janette
"the right speed, the right power"
Since 1910 leading manufacturers have selected Janette for their power needs. Janette products have earned a world-wide reputation for superior construction and dependable performance. "Manufactured by Janette" appears on hundreds of manufacturers' products—proof of proud association of great names.
JANETTE PRODUCTS
GEAR-MOTORS
Sub-fractional, fractional and integral H.P. ratings
SPEED REDUCERS ★ ROTARY CONVERTERS ★ MOTOR GENERATORS
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Aircraft Industry Assured Of Continuous Production

The aircraft industry was recently assured that in 1956, when the Air Force goal of 143 wings is reached, there will be no sudden cessation of military aircraft production.

Major General William H. Tunner, deputy commander of Air Materiel Command, told the Washington chapter of the National Security Industrial Association that the Air Force has four "insurance policies" against widespread cancellations of contracts, such as threw the industrial world into a turmoil after World War II.

He listed them as:

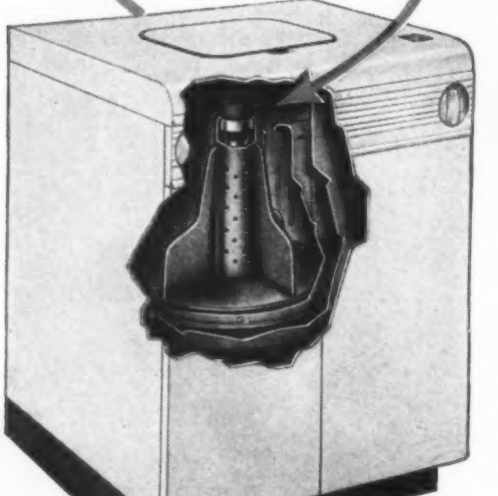
1. The production stretchout: The original programming called for a much more rapid buildup to reach an earlier peak. That "would have necessitated expanding our production facilities to a point far beyond the capacity of our normal peacetime economy to reabsorb them when the defense production peak was reached and passed. We decided instead to stretch production over a longer period, to ease the eventual transition to normal."

2. The production readjustment program: "As industry has geared up to turn out the materiel of supersonic airpower—much of it radically new—we have found it to be producing more from a given quantity of resources than we had actually reported. We are now beginning to make a more realistic evaluation, in the light of our production experience during the past two years."

3. The Production Acceleration Insurance Program (PAIP): "This aims to establish certain critical mobilization resources within the structure of our normal production facilities. Our purpose is to create a factor of expandability, with minimum disruption of normal production and maximum possibilities for quick mobilization."

4. Contract maintenance: "Contracts are being signed with airframe and engine manufacturers to handle the overload of aircraft maintenance which is already exceeding the capacity of existing Air Force maintenance facilities. This has advantages for both industry and the Air Force. It will save us the prohibitive cost of erecting new facilities of our own to handle what we know will be

(Continued on Page 236)



LORD Bonded-Rubber Mountings used in basic design help to increase sales for leading appliance manufacturers. Inherent Vibration and Shock are actually "designed out" of the appliance, resulting in smooth operation and longer service life. For instance, the famous Blackstone Automatic Washer does its work quietly and efficiently with the "spin dry" basket mounted on the Lord bonded-rubber flexible mounting. This Lord bonded-rubber flexible mounting compensates for unbalanced loading of the "spin dryer" during the clothes-drying cycle. This is another of many examples in which Lord engineering experience and precision manufacturing technique combine to advantage in basic design to speed up and increase end product sales in highly competitive markets. Consider increasing consumer preference for your product by using Lord vibration and shock control mountings.

BURBANK, CALIFORNIA 233 South Third Street	DALLAS, TEXAS 413 Fidelity Union Life Building	PHILADELPHIA 7, PENNSYLVANIA 725 Widener Building	DAYTON 2, OHIO 410 West First Street
DETROIT 2, MICHIGAN 7310 Woodward Ave.	NEW YORK 16, NEW YORK 280 Madison Avenue	CHICAGO 11, ILLINOIS 520 N. Michigan Ave.	ERIE, PENNSYLVANIA 1635 West 12th Street

LORD MANUFACTURING COMPANY • ERIE, PA.

LORD BONDED RUBBER

Headquarters for
VIBRATION CONTROL

Advertisement

Appliance Manufacturers Profit By Using Lord Mountings To Isolate Vibration and Shock

Efforts to "design out" of modern appliances the irritating and damaging factors of vibration and shock meet with considerable success when Lord Mountings and Bonded-Rubber parts are selected while the product is in the early design stage.

An oustanding example is the famous Blackstone Automatic Washer, boon to housewives the world over. The use of a specially designed Lord bonded neoprene flexible coupling isolates the normal vibration which would accrue to the uneven loading of the tub during the spinning cycle. This coupling not only drives the tub with its full load of clothes during the spin cycle, but acts as a pivot, allowing the tub to float freely within the outer shell.

This combined flexible drive and pivot prevents transfer of shock and vibration to the base and outer shell of the washer. During the draining cycle, the Lord coupling supports the entire weight of the tub, the clothes, and a full load of water, a total weight of approximately 200 pounds. In each of its functions this Lord full bonded neoprene coupling is stressed in shear, resulting in maximum flexibility.

Other examples of product improvement by isolating vibration and shock through the use of Lord Precision Bonded-Rubber Products are found in room air conditioners, air circulating fans, food and juice mixers, ice cube dispensers, portable sanders, to name but a few.

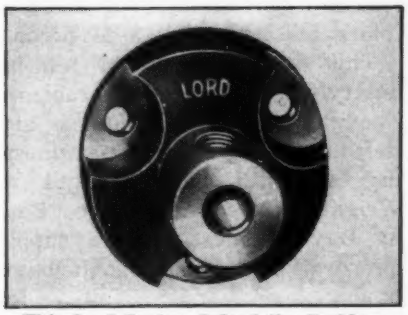
Lord Manufacturing Company, Erie, Pa. invites inquiries from design engineers whose problems involve vibration and shock isolation or power transmission.

Bonded Neoprene Hub Solves Fan Noise Problem

Recently, a prominent manufacturer had produced an attractive and efficient window-type air conditioner. However a high level of motor noise caused purchasers to favor competitive units. Investigation showed that although motor mounts were doing a satisfactory job of isolating motor noise from

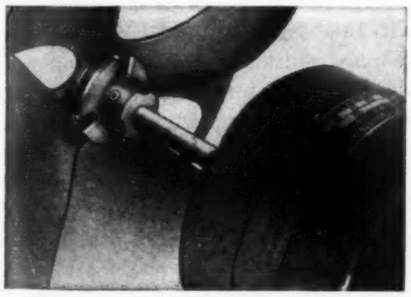
(Continued on next page)

the cabinet, they did not prevent noise from being carried through the motor shaft into the fan blades and from there into the air stream. It was evident that corrective measures must either prevent the disturbance from reaching the fan blades, or must dampen the vibration of the blades themselves. After several unsatisfactory attempts at redesign, the fan blades were given three heavy coats of paint. This reduced the noise level somewhat. However, the process was expensive and not altogether satisfactory.



This Lord Design Solved the Problem

The problem was placed with engineers of the Lord Manufacturing Company of Erie, Pa. who specialize in the control of vibration and the production of bonded rubber parts. Within a short time a design for a new hub was submitted for consideration.



The new hub consisted of a stamped aluminum washer and a zinc die casting between which was bonded neoprene of proper stiffness to insure fan stability and maximum vibration isolation. There was no metallic path for vibration to follow, and the neoprene formed a very effective "sound dam" between shaft and fan. Tests determined that motor noise almost entirely disappeared, and operating noise fell to such a low level that even the most critical members of the staff were satisfied. Cost figures proved that the bonded neoprene hub was less expensive than the staked hub previously used plus the three coat paint job on the fan.

For a quarter century Lord has solved the vibration and shock problems of industry. In the manufacture of home appliances the necessity for controlling vibration is of first importance.

For example in the Dormeyer Blender used in thousands of homes every day, a Lord Flexible Coupling provides smooth power delivery for the blending action and accommodates shaft misalignment between motor and blades. In addition, four Lord Mountings prevent vibration from telegraphing to the blending jar. These precision Lord Mountings also assure accurate positioning of the jar on the base.

Whatever your design problem may be . . . vibration, shock, or smooth power transmission . . . we welcome the opportunity to help you.

BURBANK, CALIFORNIA 233 South Third Street	**DALLAS, TEXAS** 413 Fidelity Union Life Building	**PHILADELPHIA 7, PENNSYLVANIA** 725 Widener Building	**DAYTON 2, OHIO** 410 West First Street
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LORD MANUFACTURING COMPANY • ERIE, PA.

LORD BONDED RUBBER

Headquarters for
VIBRATION CONTROL

Engineering News

(*Continued from Page* 233)

increasing maintenance needs. Moreover, it should be into full operation at about the same time that procurement of new aircraft begins to taper off toward the subsistence level."

General Tunner said that in addition to these four insurance policies, Air Materiel Command is taking a fifth step within the command itself. He referred to the decentralization program, which "places authority and responsibility for logistical service closer to the customer and the things he needs."

This idea was borrowed from industry which had similar problems. Though airframes, engines and items requiring extensive engineering are still being bought at Wright-Patterson Air Force Base at Dayton, most of the supply items will be purchased at the bases having prime responsibility for these items.

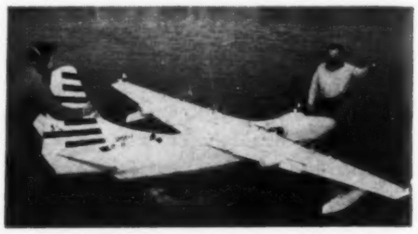
Nation's Nickel Supply To Get Substantial Boost

The nation's supply of nickel, one of the most critical of all materials, will be boosted substantially during the next several years from the only known major deposit within the continental United States. Final product of the operation will be ingots of ferronickel, containing at least 25 per cent nickel and not more than 75 per cent iron. Ferronickel can be substituted readily for pure nickel in the production of stainless and various other low-alloy steels. It is not considered practicable as a substitute for pure nickel in the production of high-alloy steels.

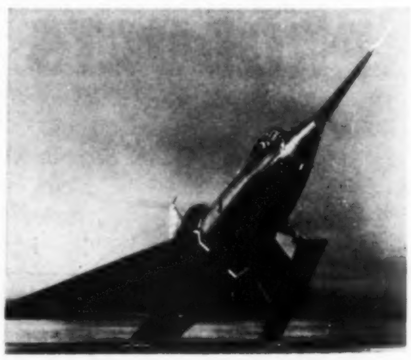
The big mountain deposit in southwestern Oregon will be worked by the Hanna Coal & Ore Corp. and the Hanna Nickel Smelting Co. Production of from 95 to 125 million pounds is expected, with the bulk of the scheduled output sold to the American steel industry.

Net result of the project will be to release substantial amounts of pure nickel for specialized defense and industrial uses. The Oregon undertaking, however, will leave the U. S. far short of the goal of 190.000 tons of nickel per year by 1955 established by the Defense Production Administration.

Engineering News



Flying model airplanes such as the gasoline - powered model shown above were built by Consolidated Vultee Aircraft Corp. in developing the Navy Sea Dart jet fighter, pictured below on shore. A series of eight radio-controlled dynamically similar models, scaled down in size, power, weight and balance, preceded the full-scale seaplane. One of the models was a sweptwing transonic seaplane, the first to have wings blended into the hull. However, Convair engineers, convinced that a delta wing is more suited to supersonic flight than a sweptwing, specified the former in the final Sea Dart model. A model costs between 15 and 20 thousands of dollars and requires three months to build; use of models eliminates the need for full-scale planes costing from 5 to 20 millions of dollars



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Factory space of the **E. B. Sewall Mfg. Co.** has been nearly doubled, and the company's address has been changed to 705 Raymond Ave., St. Paul 14, Minn. In addition to a complete line of standard pitch stock sprockets, the firm produces special sprockets as well as cut spur, helical, straight bevel and spiral bevel gears, worms and machine-cut gear racks.

•

Formerly manager of eastern division sales, E. M. Richardson has been named general sales manager of **Nice Ball Bearing Co.,** Philadelphia. He joined the company as a sales engineer in 1945.

NEW LINCOLN PLANT CREATED BY INCENTIVE-INSPIRED CO-ACTION IN DEVELOPING POSSIBILITIES IN PRODUCT

© LE Co. 1953

WELDED STEEL DESIGN SIMPLIFIES PRODUCTION . . . CUTS COST ON MACHINE TOOLS

by **William B. Boice**

Boice-Crane Company, Toledo, Ohio

COSTLY machining operations like milling castings can be eliminated by designing for welded steel construction. On our jointer, for example, the top surface is now finish ground to close tolerance in one setup after welded assembly. Wherever machining is required, with steel construction precision tolerances are often held in one cut as compared to rough and finish cuts required on most castings.

Since steel is twice as rigid as gray iron, less material is needed to resist deflection under load. If made from castings, our jointer would weigh twice as much and still be subject to inaccuracies from deflection and warpage no longer experienced in the present welded steel construction.

With less material, less machining and fitting involved, shop costs are reduced. Furthermore, the modern appearance achieved with the welded design has greatly improved selling appeal.

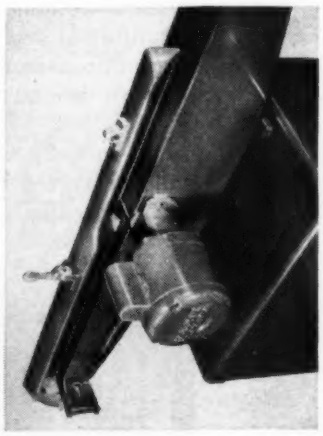


Fig. 3. Welded steel design *of 8" jointer is stronger, more rigid yet weighs half as much and costs less than cast construction. Courtesy, Boice-Crane Co.*

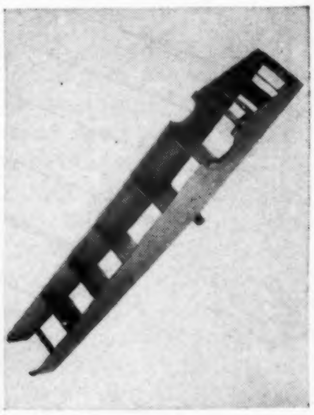


Fig. 4. Efficient girder-like structure *forms rugged frame for table. Top is welded to frame with intermittent welds and finish ground in one setting.*

WELDED DESIGN ALWAYS SAVES STEEL AND LOWERS COST

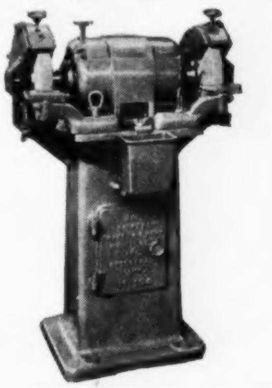


Fig. 1. Original construction *of pedestal grinder required costly milling and drilling using heavy machine tool equipment. Casting had to be filled and painted to obtain quality finish for sales appeal.*

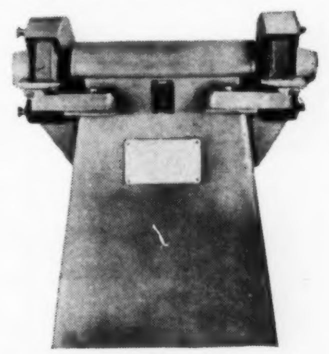


Fig. 2. Present welded steel design. *Quality of product and appearance improved to enhance sales appeal. Stability increased by lowering motor into pedestal base. Weight is cut 35% yet product is more rigid and costs 12% less to produce. Courtesy, The Bridgeport Safety Emery Wheel Co., Inc., Bridgeport, Conn.*

MORE PROOF

Machine Design Sheets available on request. Designers and Engineers write on your letterhead to Dept. 1102,

THE LINCOLN ELECTRIC COMPANY

CLEVELAND 17, OHIO

THE WORLD'S LARGEST MANUFACTURER OF ARC WELDING EQUIPMENT

Engineering News

New Machine Forms One-Piece Exhaust Cones

Inner exhaust cones for jet engines are rolled from heavy stainless steel sheets in a matter of minutes with a new machine designed by Reed Engineering Co. Shown in use at Ryan Aeronautical Co., the new machine eliminates many operations formerly required to build the cones in two pieces and weld them together.

With the new cone roller, a sheet of pattern-cut stainless steel is placed between the tapered rolls of the machine, pushbuttons are depressed, and a complete cone rolls out. It is placed on an automatic Heliarc welding machine and the longitudinal seam is welded in one pass. Cones formed by this method are sound structurally and claimed to be better in quality than those built by the former method, which involved rolling a truncated cone and capping it with a smaller cone.

•

O & S Bearing Co. of Detroit and its solely owned subsidiary, the Neveroil Products Co. of Whitmore Lake, Mich., have been consolidated. The new company will be known as the **O & S Bearing & Mfg.** Co. and will be located at 777 West Eight Mile Rd., Whitmore Lake, Mich. O & S Bearing Co. will maintain Detroit sales and service offices.

Engineering News

Materials To Be Discussed At Three-Day Conference

A three-day conference on basic materials available to manufacturers will be held at the Hotel Roosevelt, New York, June 16 to 18. Properties and potentialities of a whole range of new materials will be discussed. Sponsored by executives of twenty leading companies, the conference is being held simultaneously with the materials exposition announced in January (Page 226).

In addition to the discussion of the new materials, there will be sessions on new applications of older, more standard materials. Subjects scheduled for discussion include economic factors of materials newly developed and those still in the research stage, product design from a materials standpoint, organization of materials engineering departments, and sources of information about new materials and their special applications. More than 2000 experts are expected to be present to lead these discussions and answer questions.

The conference is open to management executives, project engineers, product engineers, materials engineers, production experts, research engineers and sales and marketing executives. Advance registration cards may be obtained from Clapp and Poliak Inc., the exposition management, at 341 Madison Avenue, New York 17.

Shell Molding Grows in Popularity

Indicating the growth of the shell molding process, figures released by the plastics division of Monsanto Chemical Co. show that production of resins used in this process has more than doubled each year since 1950.

Shell molding is being used in both large and small foundries, with 20 foundries in actual production last year and more than 100 beyond the development stage but waiting for machines or patterns. Most shell molding units are multiple-station machines, varying from 2 to 24. Approximately 300

stations were producing shells for castings last year, and it is estimated that by the end of this year three times as many stations will be in operation.

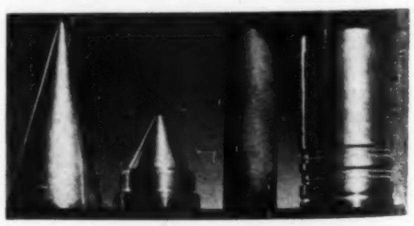
Versatility of the process has been demonstrated by the successful casting of large-volume parts. Also, shell molding has proved adaptable to the casting of nodular iron, a recent metallurgical discovery in the foundry industry.

Tungsten Carbide Gives Armor Piercing Shells "Sunday Punch"

Recently released from the "classified" list is the story of tungsten carbide's part in the Normandy invasion. One of the hardest substances made by man, it served as the hard core of a shell which pierced the armor of the heaviest German tanks—even when a hit was made at a 20-degree angle.

On July 7, 1944, General Eisenhower, then Supreme Commander of the Allied Expeditionary Forces, informed the Detroit Ordnance District that the Allied offensive was being seriously hampered by lack of a shell which would penetrate the Nazi tanks. Two days later, the Carboloy Dept. of General Electric Co. had produced 10 cores for testing. In less than two weeks from the receipt of the request for such a shell, they were in quantity production and being flown to France. Shells of the same type are now being used in Korea.

Parts of armor piercing shell are, left to right, windshield, nosepiece, tungsten carbide core and body



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Formerly manager of outside sales for **Standard Pressed Steel Co.**, Jenkintown, Pa., George A. Gade has been named vice president in charge of sales.

Meetings

AND EXPOSITIONS

Mar. 16-20—
National Association of Corrosion Engineers. Annual conference to be held at Hotel Sherman, Chicago, Ill. A. B. Campbell, 919 Milam Bldg., Houston 2, Texas, is secretary.

Mar. 17-18—
Steel Founders' Society. Annual meeting to be held at the Edgewater Beach Hotel, Chicago, Ill. Additional information may be obtained from society headquarters, 920 Midland Bldg., Cleveland, O.

Mar. 18-20—
American Society of Tool Engineers. Annual meeting to be held at Hotel Statler, Detroit, Mich. Harry E. Conrad, 10700 Puritan Ave., Detroit 21, Mich., is executive secretary.

Mar. 23-27—
American Society for Metals. Eighth western metal exposition to be held at the Pan-Pacific Auditorium, Los Angeles, Calif. concurrently with the Western Metal Congress which is to be held at the Statler Hotel, Los Angeles, Calif. Additional information may be obtained from exposition headquarters, 7619 Beverly Blvd., Los Angeles, Calif.

Mar. 25-27—
Society of Automotive Engineers. First national production meeting to be held at the Statler Hotel, Cleveland, O. Additional information may be obtained from society headquarters, 29 West 39th St., New York 18, N. Y.

Apr. 20-22—
Metal Powder Association: Annual meeting and exhibit to be held

Meetings and Expositions

at Hotel Cleveland, Cleveland, O. Robert L. Ziegfeld, 420 Lexington Ave., New York 17, N. Y. is secretary.

Mar. 31-Apr. 2—
International Magnesium Exposition to be held at National Guard Armory, Washington, D. C. Calvin H. Corey, 261 Constitution Ave., Washington 1, D. C., is general chairman.

Apr. 13-15—
American Society of Lubrication Engineers. Eighth annual meeting to be held at Hotel Statler, Boston, Mass. Additional information may be obtained from society headquarters, 343 South Dearborn St., Chicago 4, Ill.

Apr. 20-23—
Packaging Machinery Manufacturers Institute. Annual packaging exposition to be held at the Navy Pier, Chicago, Ill. Additional information may be obtained from society headquarters,, 342 Madison Ave., New York 17, N. Y.

Apr. 20-23—
Society of Automotive Engineers. Aeronautic production forum, national aeronautic meeting and aircraft engineering display to be held at Hotels Governor Clinton & Statler, New York, N. Y. John A. C. Warner, 29 West 39th St., New York 18, N. Y., is secretary.

Apr. 27-28—
American Zinc Institute Inc. Thirty-fifth annual meeting to be held at Hotel Statler, St. Louis, Mo. Ernest V. Gent, 60 East 42nd St., New York 17, N. Y., is secretary.

Apr. 26-30—
American Ceramic Society. Annual meeting to be held at Hotel Statler, New York, N. Y. Charles S. Pearce, 2525 North High St., Columbus 2, O., is secretary.

Design Abstracts

(*Continued from Page* 179)

represents a loss which can be minimized in design by having the magnetic field overlap the electrodes by an amount equal to two or three times the air gap length.

Of all the electromagnetic pumps, this type is the simplest and inherently the most rugged and dependable. The maintaining of sufficiently cool electrical windings is a common problem; in this type it can be minimized by moving the exciting windings away from the hot liquid duct and by insulating between the duct and the pole faces. Insulation between the duct and the pole faces requires more exciting current in the exciting windings, and consequently a higher field loss, but this is not excessive. Units in which the windings were cooled by natural convection have operated with fluid temperatures as high as 800 F without excessive winding temperatures, making electrical varnish insulation usable. Other models have used very low voltage, high current windings connected in series with the "armature" in the manner of a series connected dc motor. In this arrangement, stainless steel was used as electrical insulation in the windings, as it is in the pump section or fluid duct.

These pumps have the shortcoming of requiring an unusually high current supply. The pump section —the equivalent armature—is a single turn armature, and at reasonable values of fluid velocities and flux densities can develop only relatively low back voltage. In addition, the "armature" is shunted both by the walls of the pump and the fluid at the extremities of the magnetic field—two paths of inherently low resistance. Consequently these pumps are forced to operate at low voltages, in the neighborhood of one volt, and the current requirements are high. This characteristic has prevented use in applications where large fluid horsepower is required. However, where the bulk and expense of high-current power supplies are not prohibitive, they have proved to be simple and dependable and have been built for capacities as high as

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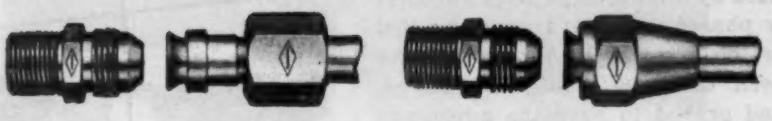

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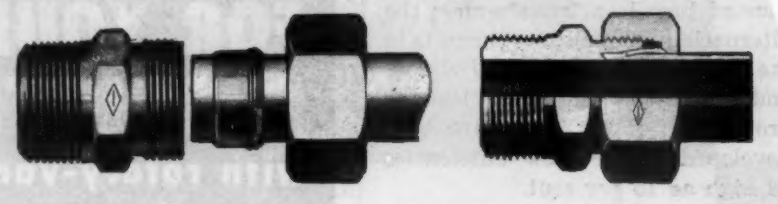

Fitting consists of 3 pieces: body, nut and sleeve.

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Design Abstracts

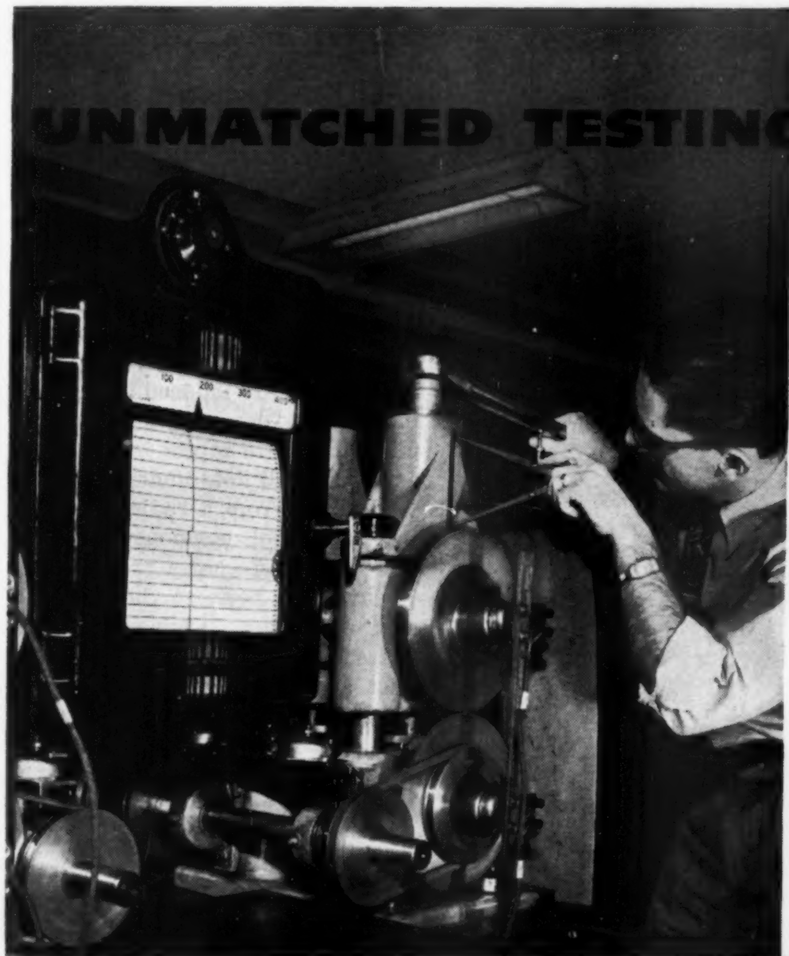
about 400 gpm and for heads as high as 100 ft.

Faraday AC Pump: High currents can most readily be obtained from a transformer. A Faraday pump might be made to work on alternating current if the field were excited by alternating current properly phased with the voltage applied to the armature. A number have been designed, built, and tested, and proved to have the advantage envisioned—that of requiring no bulky or special power supplies. They have, in general, the elements shown in *Fig.* 1 and possess the assets of being rugged, simple and dependable. However, additional losses are large and efficiency is appreciably less than that obtainable from Faraday dc pumps. One of the major additional losses is due to the fact that the fluid acts as a shorted turn in a transformer; the alternating field induces currents in the fluid which cause an I^2R loss and increase the flux leakage around the gap. Units have been developed which show efficiencies as high as 15 per cent.

A pump of this type is shown in *Fig.* 2. The current transformer which produces the high current has a magnetic core which is common with the core for the magnetic circuit, making a single unit. A series connection is used so that the flux in the gap and the current in the fluid are substantially in time phase.

Because of low efficiency and the bulky magnetic circuit, applications have been limited to small sizes. Free convection cooling of the primary windings is not difficult; no special power source is required. The small pumps have been generally used for laboratory purposes where efficiency is less of a consideration than convenience.

Helical Flow Induction Pump: This type of electromagnetic pump resembles an induction motor in principle and in operating characteristics. The net effect is that of an induction motor in which the rotor conductors have moved into the air gap, become a fluid enclosed in a thin hollow cylinder and are separated into multiple helical



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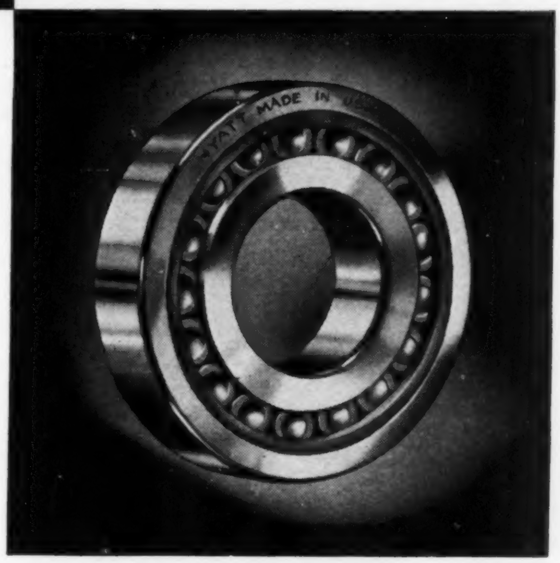

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paths. These elements are shown schematically in ***Fig.* 3**.

A three-phase winding acts to create a rotating multiple field. This field, by inducing voltages in the fluid, causes a pattern of currents to flow in the fluid similar to those which flow in the rotor of an induction motor. The interaction between the field and the currents which are induced in the fluid produces a force which causes the fluid to tend to rotate. This force, exerted on all fluid under the poles, is resolved from a radial direction into an axial component by the helical vane so that a pressure rise is developed between the two ends of the cylinder. Copper rings are brazed to the inside wall of the duct at its two ends to provide a return path for the current, which flows axially in one direction under one pole and in the opposite direction under the adjacent pole.

"Slip" Determines Pressure

Performance is comparable in many respects to that of an induction motor with a high air gap and a high-resistance rotor. At a flow for which the fluid is rotating at the same speed as the field, the pump theoretically develops no pressure; corresponding to synchronous speed in an induction motor.

Actually, because of the internal hydraulic losses, this point is reached at a flow somewhat less than synchronous flow. The "slip" of the fluid with respect to the field is similar to the familiar slip of an induction motor. The entire performance is a function of the slip and the impressed voltage, the pressure rising as the slip increases. As in other electromagnetic pumps, the duct walls act as shunt current paths and appear as an equivalent high core loss, or as a high-resistance stalled rotor electrically in parallel with the fluid rotor. One loss finds no parallel in the induction motor; the fluid, flowing axially in the gap, has induced in it a circumferential voltage gradient. This causes currents to circulate in the zone where the fluid enters and leaves the field.

A number of these pumps have

been built with moderate success. Best applications are where relatively high pressures and low flows are required, and where size is at a premium. The high pressure characteristic can be obtained by having a flat helix in the fluid channel so that, in effect, the fluid must pass over and be acted on by each pole a number of times as it flows through the pump. Heads as high as 260 feet of sodium have been developed.

One unit, weighing 1500 pounds, required 1000 cfm of air for cooling and delivered 400 gpm of sodium against a developed head of 60 feet. The unit required 25 cps power, and operated at a power factor of 80 per cent.

Linear Induction Pump: A fourth type which has been the subject of some development is the linear induction type. In operating principle, it is identical to the helical flow pump; however, its elements are arranged in a different form. The fluid is contained in a duct of rectangular cross section, connected at each end through transition sections to the inlet and discharge nozzles. In practice, the aspect ratio of the duct cross section is of the order of magnitude of 25. A polyphase multipole ac winding is located on both sides of the duct, with the axes of the coils perpendicular to both the large dimension of the duct cross section and the direction of flow. The winding is, of course, contained in a suitable core and properly supported mechanically. Thermal insulation is interposed between the duct and the magnetic core to minimize heat loss from the fluid and to make it possible to maintain a reasonable winding temperature. An expansion joint is provided to allow for the temperature differential existing between the hot duct and the relatively cold outer walls of the pump. Most of these elements appear in *Fig.* 4 which shows a section "cut" through a model in the middle, illustrating typical construction. The fluid channel is the rectangular opening in the middle. It is divided into eight smaller channels by vanes which are only to provide stiffness to the duct

Design Abstracts

walls. Cooling air openings are on opposite sides of the outer walls.

When a three-phase alternating voltage is applied to the windings a multipole field is established with adjacent poles of alternate polarity. This field moves down the duct one pole pitch every half cycle. Currents are induced in the fluid which tend to make the fluid follow the field. The behavior is similar to that which occurs in the helical flow type. However, because the field is moving in the same direction as the fluid is required to flow, no guide vanes are required and the force which the moving field exerts on the fluid, divided by the cross section area of the duct, is the pressure developed. The same relation between flow, synchronous flow, impressed voltage, and pressure exist in this pump as exist in the helical flow pump; however, the type of end loss noted in the helical flow pump has no equivalent in the linear induction pump.

This type is best suited where relatively large flows at moderate heads are required and where space and power supplies are at a premium. Using standard electrical insulation, these pumps require forced convection cooling systems of reasonable size. As in the case of the helical flow induction pump, the windings are cooled by the forced circulation of air through suitably designed passages in the stator iron.

One unit of this type has delivered 1200 gpm of 850 F sodium for 110 ft developed head at 300 volts, 288 amps, 0.45 power factor, 60 cps. The unit weighed 6430 pounds and required 2000 cfm of cooling air.

General Considerations: By comparison to standard centrifugal pumps for conventional usage, the electromagnetic pumps suffer in efficiency and size. However, the convenience or, in some cases, the necessity of having completely leakless operation has warranted their development and use.

Development has been rapid; the pumps have advanced in a few years from an engineering curiosity to a point where they are usable pieces of equipment and amenable to design in a fairly straightfor-

ward manner. It is reasonable to expect that future development will lead to more improved designs, and that the pumping problem will be removed as a deterrent to more widespread use of liquid metals.

From a paper entitled "Electromagnetic Pumps for High Temperature Liquid Metal" presented at the ASME Annual Meeting in New York, N. Y., December 1952.

Writing Sells Ideas

By A. J. Casser
Technical Writer
Allis-Chalmers Mfg. Co.
Milwaukee, Wis.

RECOGNITION of an engineer's achievements and professional progress often depends on adequate and effective expression in writing. And, while technical writing may not be easy for many individuals, the ability to put thoughts on paper clearly and concisely does have worthwhile compensations.

As engineers, your company's name and reputation are as important as your own degree. The company's reputation is obtained mainly from the collective reputation of its individual engineers. Technical articles not only increase the company's prestige but your own as well. If you doubt this, check the big names in engineering. They're the names you've read again and again until they have become known authorities.

Technical writing takes plenty of thought and research and stick-to-itiveness. The author must state his subject clearly and must hold the attention of his readers throughout the article. There is no excuse for writing a long list of facts and expecting the reader to go beyond the first paragraph.

When a job is well done, when a tough problem is solved successfully, or when a new product is developed, it deserves publicity. Unquestionably, there is a personal satisfaction for the author in writing about such a subject. Besides seeing his material in print, he is providing information of real value to his readers—information that will often help members in other

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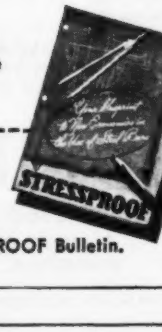

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departments of his own company.

There is a growing demand for technical writing and it is financially profitable. The primary reason for technical writing, however, should be to increase your prestige as well as your company's. Gaining recognition by this means will in time give you a reputation as an authority in your field. It will put you in good stead with any other company that may need a consultant engineer.

You might ask yourself, "Am I qualified to write?" The answer is yes, whenever you have an active interest in a subject, have personally acquired fresh information and have strong ideas that demand expression.

Fellow engineers find your work interesting because they know so little about it. In doing a particular job, you may have information unavailable to anyone else; you may be using different methods or discovering new facts on theories. Remember, what is old and familiar to you is very likely new and interesting to others.

What to Write: You should write about a subject that is of particular interest to a certain group of readers. Select the magazine or technical journal in which you want your article to appear and then write to that group of readers. There are many subjects that can be broadly grouped into a number of definite types. The following may serve as a pattern.

1. Product Design. Generally offers the most readily available material for an article. Because design information tends to read like sales bulletin copy, only unbiased treatment is acceptable. Describing a new product through a series of design problems and their solutions usually avoids the obvious commercial nature of the product design article.
2. Research and Test Findings. This material is always eagerly sought by technical magazines. Besides maintaining your own and company prestige, it is often used as reference material by other engineers for years to come.
3. Trends Story. Appears in many


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publications at least once a year. Since this information must come from manufacturers and users of equipment, an article on trends in design, use, merchandising, etc., is usually welcome.

4. NEW METHODS OF UTILIZING EQUIPMENT. Also, short-cut hints as used in your own or customers' manufacturing operations.
5. USER CASE HISTORY. Exemplifies the successful operation of equipment in a completed installation.
6. UNUSUAL APPLICATIONS. Used singly to interest a broad group of readers, or multiplied to probe a new market and to start the industrial world thinking.
7. MAINTENANCE AND CONSERVATION. Advice on equipment that you are most familiar with and that you know best. This is always read by operation and maintenance men.
8. HOW TO BUY. Written from any unbiased point of view, giving readers specific information on industry standards, acceptance tests, estimation of relative costs and required equipment.
9. SUCCESSFUL IDEAS ON HOW TO SELL OR MERCHANDISE. This is likely to be more and more in demand for normally competitive markets.
10. "INTO THE FUTURE" MATERIAL. Very significant when predictions are carefully projected from authoritative data. A single idea or article of this kind can influence an entire industry.

These subjects are typical of those which you can write from material available in the course of day-to-day work. Remember, too, that one idea can often be worked into several articles for different publications in different fields.

How to Start: One of the easiest methods of starting is to just look about you and conduct a market survey. This can be accomplished at your company's library or the public library by merely thumbing through a half-dozen industrial publications. When paging through these magazines, make notes on what types of articles are used and how long they are. Scan the article and determine whether the author is "popularizing" or if he is using straight technical writing.

The difference between the two

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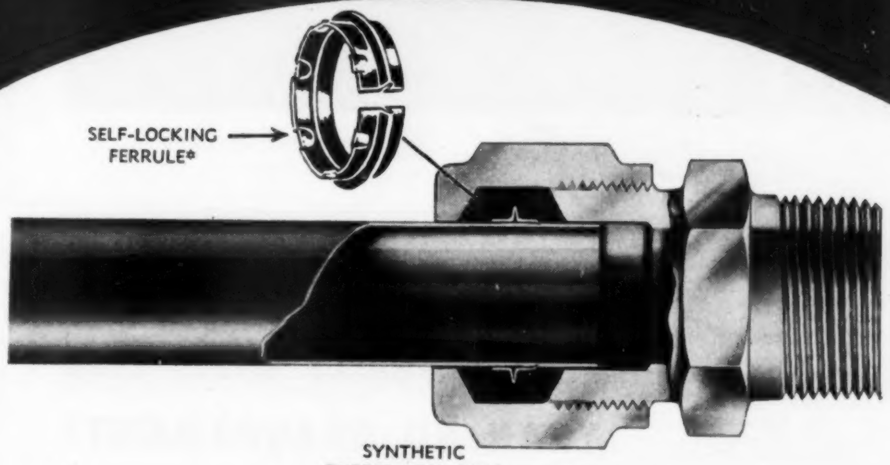

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is that if a writer presents his material or technical information in a manner easily understood by the average reader, he is "popularizing." This is an informal style of writing where the author avoids using technical language. However, if he cannot avoid using technical terms, he will define them so the average reader can understand the article without much effort. On the other hand, straight technical writing results when the writer feels that his reputation depends on what other engineers think of him, not on what the man in the street thinks. Then, people feel that the engineer cannot write exactly and completely about his subject without being technical. Also, technical writing is impersonal and objective, whereas the most readable popular treatments are likely to be personal.

Emphasis should also be placed on determining and analyzing your reader audience. Who would be interested in the subject, on what grounds can you meet your readers? That is, are you writing for other readers of your caliber and how capable are they of understanding the material you plan to present?

When evaluating your subject, and in determining whether or not it is worth writing at all, you should analyze the subject with respect to its timeliness or urgency for the industry. Has the subject been over-publicized and can it be adequately presented?

Now comes the choice of material and approach to use. This includes such factors as: What new material do I have, what part is fact and what part opinion; how does it fit into existing common knowledge, what remains to be said, and how much common knowledge can be incorporated?

An Outline Is Necessary: Manuscript preparation must begin with the development of an outline, a basic pattern of ideas and thoughts you wish to present in a logical sequence. Outlining holds your pattern of thinking to the main points that you wish to emphasize. It also forces you to recognize your purpose in writing the article and

greatly lessens the time and effort spent in revisions.

Make your outline comprehensive rather than detailed. Put the main points early, and save a strong point for the conclusion. Then, arrange the order to secure continuity of logic and interest. Let naturalness and individuality guide within these limits, and abide by known reader habits.

In checking over your outline, see if it duplicates material already published, if it is properly slanted, and whether or not you should give emphasis to the points as you have outlined them.

Important, too, suggestions for illustrations can frequently be made on the basis of your outline and this phase of your assignment completed as you prepare your manuscript.

How to Write: When starting to write from the outline, put all your ideas down in concrete form as they occur to you, without concern for finished form. Remember, you can do your final polishing later and slant your article in the form and style which is preferred.

The simplest, most concise approach is the best. Write for interested readers, not specialists. Readable style calls for simple and concrete words, simple and direct sentences, and short paragraphs. A good paragraph is from six to twelve typewritten lines. Generally, too, the article itself should be as short as possible, although this depends entirely on what you have to say and whether or not any definite length has been specified. About four double-spaced typewritten pages of "pica" type are required to make an average printed page.

Evaluation of the first rough draft should be based on these questions: Are all the ideas incorporated? Did you say what you wanted to say? Do you mean what you said—by attaching importance to a point through length of discussion as well as phrasing? How logically does it read?

Now put your story aside for a day or two to gain some perspective and a fresh outlook. Revise your manuscript until you are sat-

isfied that the organization, grammar, readability, and wording represent your best effort.

Illustrations—photographs, charts, sketches, curves, etc., — should be used whenever they help to tell your story. Include a list of illustrations with your article, definitely identifying each drawing, photograph or sketch to be used and supply enough information for a suitable caption. Good photographs will attract more readers, installation pictures are best; catalogue type blockout views are generally least desirable.

Because most magazines redraw illustrations to fit their own style, finished drawings are not ordinarily required. An original rough pencil sketch will do.

Ready to Write? Don't Forget:

1. **Pick a subject you know.**
2. **Analyze your audience.**
3. **Outline your subject.**
4. **Tell your story naturally.**
5. **Check it—is it effective?**

From an article entitled "Technical Writing Can Be Effective" which appeared in the December 1952 issue of the American Engineer.

Using Elastomers in Design

By Charles M. Miller
Materials Engineer
Northrop Aircraft, Inc.
Hawthorne, Calif.

ELASTOMER, a word recently added to our dictionaries, pertains to or denotes possession of the properties of natural rubber. It is coming into general usage to cover those rubberlike forms of matter which are not quite solid, nor are they fluid enough to call liquids. They are especially characterized by their possession of the ability to resist deformation, and when deformed, to return to their original shape quickly upon release of the deforming force. They are generally tough, with good tear and abrasion resistance, although not all exhibit these attributes.

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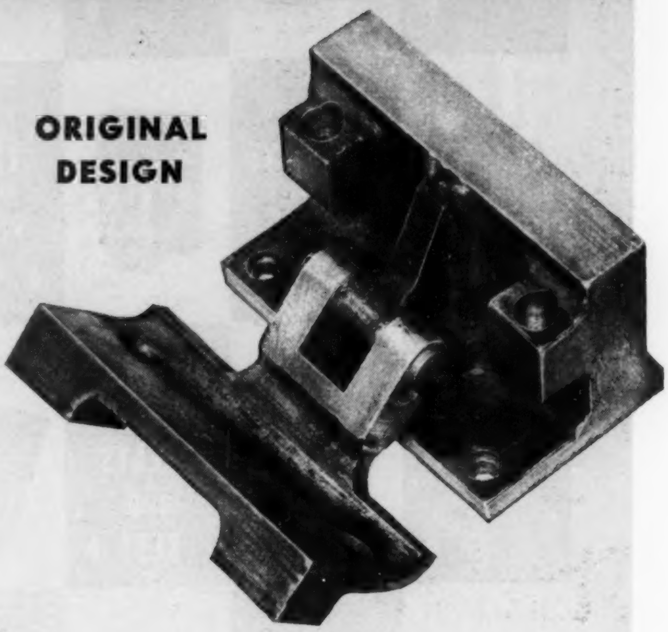

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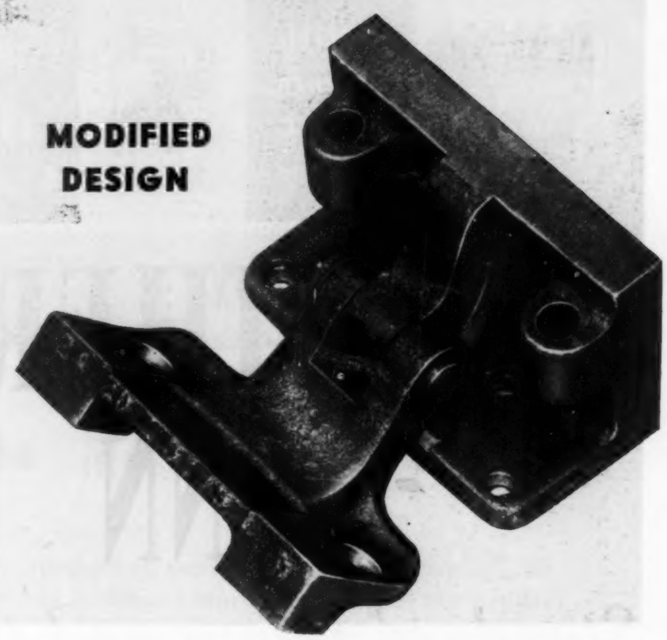

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present there is a lot not known about the exact nature of the weathering or aging action. It is most generally accepted that the combined effect of heat, light, oxygen and ozone produces an oxidation in the surface of the part. This oxidation lowers the tensile strength and affects the molecular bond which gives the elastomer its elastic properties. Should the part be under tension, the oxidation is more rapid and some natural rubber compounds have shown cracks in as short a time as seven days.

Neoprene Widely Used

To combat the occurrence of weather cracking the designer can choose a compound from several "weather resistant" groups of materials. Probably the most widely used group are the chloroprenes, more commonly known by the name neoprene. This group of compounds is made from basic polymers which are inherently resistant to oxidation and which do not use sulfur as vulcanizing agents.

Polysulfide compounds (Thiokol) are used as sealing putties and exhibit excellent weather resistance. These compounds have lower mechanical properties and are therefore not generally used for mechanical goods except as thin gaskets or coatings.

Butyl rubber, a copolymer of isobutylene and isoprene, is almost impervious to the passage of air and is quite generally used for inner tubes. Resistance to tearing is very good but resilience is poor, so that compounds are subject to cold flow. This group of compounds exhibits, in addition to good weather resistance, excellent resistance to deterioration from the newly developed synthetic lubricants and hydraulic fluids.

The elastomers most highly resistant to oxidation or weather cracking are the group known as silicone rubbers. They are compounded from organo-siliconoxide polymers and are generally not affected by ozone or rays from the sun. Tensile strength and tear resistance of this group are generally low, and care must be taken in designing for the use of these com-

pounds. Great improvements have been made in these properties, and these recent developments in the silicones have produced compounds more nearly approximating the "universal compound" than any other known elastomer.

Fuel and Oil-Resistant Types: The elastomers possessing the best resistance to petroleum-base products such as fuel and oil are the nitrile or butadiene-acrylonitrile compounds. This group cannot be softened by adjustments in the polymer as can the other synthetic rubbers, and must rely solely upon plasticizers to achieve softness. These chemical additions to soften the polymer are generally soluble in fuel especially the aromatic types. As a result, the fuel replaces the plasticizer, swells the compound 10 to 30 per cent and acts as the plasticizer in producing a softening of the compound. Upon drying, the fuel constituent that is in the compound dries out and the part shrinks, often to less than its original size. Upon re-wetting, as in refilling a dry fuel tank, the seals may have shrunk sufficiently that leaks occur until the compounds are replasticized by the fuel and again swell to fill their cavity.

The careful selection of basic polymer with just the right amount of butadiene and acrylonitrile and the correct plasticizers and fillers, has produced an excellent group of compounds now in use.

These nitrile compounds do not have very good weather resistance. For this reason there is an extensive program, in the early stages of establishment, to date-stamp all such parts to be sure that "old" parts will not be the source of failure. If these parts are replaced at periodic overhaul before they give trouble, fuel systems failures from this source should be cut down.

For incidental spillage of fuel or oil the chloroprene group is quite satisfactory. Here there is a combination of factors that usually applies. Such applications are generally also subject to weathering, and a decision must be made as to which would be the most damaging, the fuel or oil, should it get on the seal, or the oxidation to which the

seal would be subjected all the time. It should be emphasized that once an elastomer is weather cracked, nothing less than replacement can be done to repair it, as the cracks will progress and finally, failure of the seal will occur.

In certain lubricating oils the silicones again come forward. Silicone rubber O-ring seals are used on diesel engines, the only elastomer capable of resisting deterioration by both the temperature and the oil. At temperatures of 200 to 400 F these are the only elastomers that will be serviceable as oil valve seats and diaphragms.

Hydraulic Fluid-Resistant Types: The hydraulic fluid most commonly used in the aviation industry is the red petroleum base oil. This low aniline point fluid causes high swell of almost all elastomers, the most resistant of which are the Thiokols. This elastomer group has lower mechanical properties and is not used for mechanical goods except as flat gasketing or in coatings.

Nitrile is the next best polymer, and is most widely used for seals and diaphragms. These compounds are quite similar to the lubricating oil resistant stocks. While chloroprene and silicone compounds are fairly resistant to lubricating oil they are swelled to excess by the red petroleum base hydraulic fluid.

Here again, as with fuel immersion, even the best nitrile compounds undergo a progressive shrinkage on successive wetting and drying, but the action is not as severe as with aromatic fuels.

The use of the new low-flammability hydraulic fluids such as AMS 3150 has required the development of a new series of compounds since nitrile and other oil-resistant types are excessively swelled and softened by the phosphate ester fluids. Butyl rubber has proven to be the most swell resistant of the polymers available at this time. Here a low tear and low compression set compound is used to make the seals in these hydraulic systems. The designs of the packing glands and O-ring grooves must be carefully worked out to allow for the shortcomings of the sealing material. Care must

Design Abstracts

be taken to prevent the contamination of the hydraulic fluid with petroleum-base oils as these packings may swell from 50 to 250 per cent on immersion in low-aniline point petroleum fluids.

High Temperature-Resistant Types: All of these elastomers are vulcanized, or oxidized as are the silicones, at high temperature which is often referred to as the "cure". Exposure to higher temperature further "cures" the compound or degredation may occur.

The best high temperature-resistant elastomers are the silicone rubbers. They are usable under continuous service to 400 F or more, depending on the application. The next best group are the nitrile compounds. These, however, will harden and lose their elasticity along with a reduction in tensile strength if subjected to heating at temperatures exceeding 250 F. On a comparative test for 100 hours of intermittent heating to 250 F for one to two hours at each cycle, nitrile compounds suffered over 50 per cent reduction in tensile strength and elongation while the silicone compounds did not lose in either of these properties. Chloroprene compounds are also used for high-temperature service, but are generally not as good as the nitrile elastomers.

The exposure of the compound to an atmosphere containing free oxygen will produce an embrittling glaze on the surface of some nitrile compounds, while surface crust will break readily. Some cracks may appear without flexing the part, and may be caused by surface shrinkage. Should this same compound be protected from the air, as between flanges, the surface will not be so glazed and will remain rubbery in texture. In one such test at 400 F the nitrile compound between the flanges did not glaze or crack, but the hardness increased appreciably. This test showed clearly the effects of flanges in protecting the gasket, and illustrates the importance of design in utilization of the basic properties of the material.

Low Temperature-Resistant

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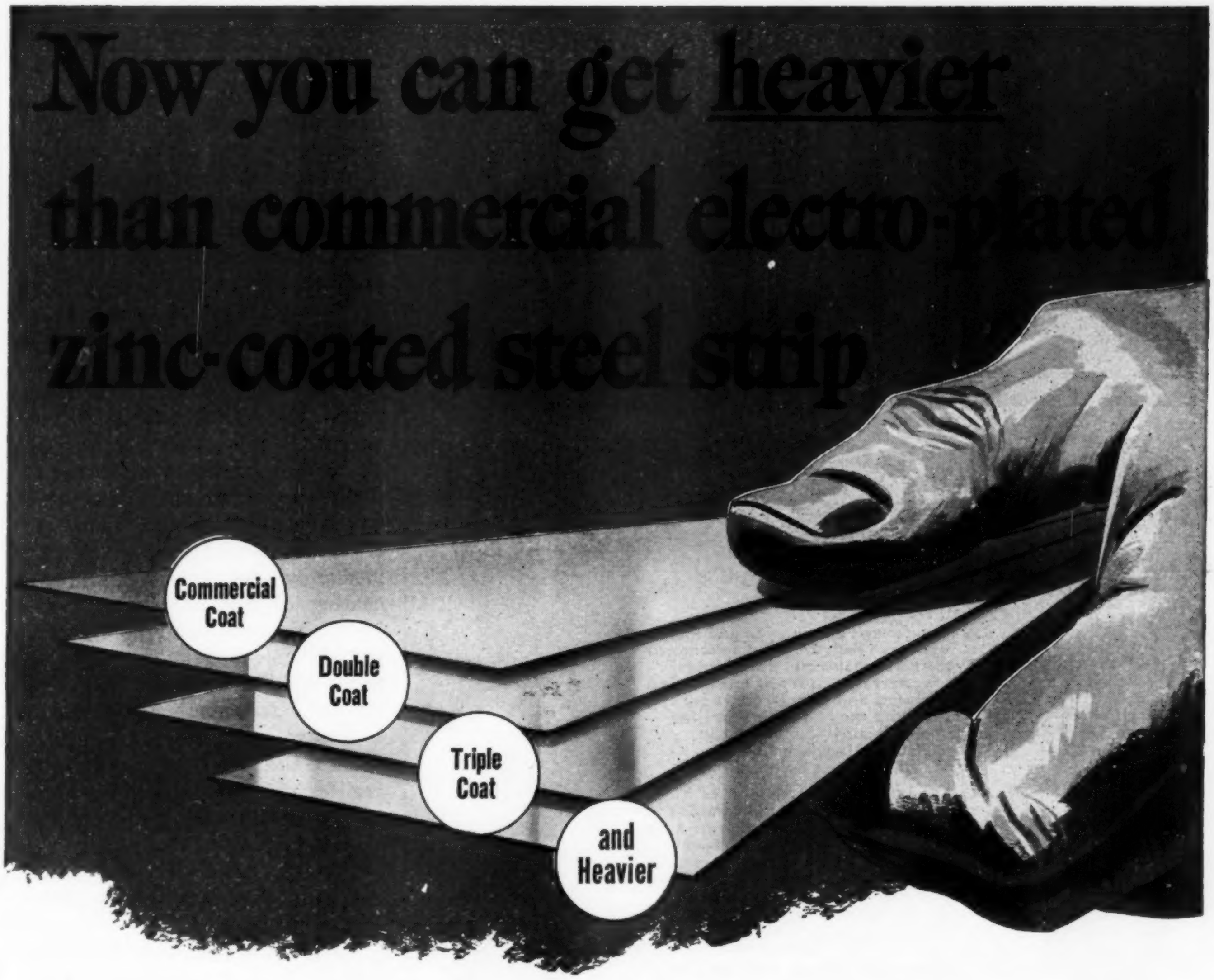

When your production standards demand extra protection from corrosion you can get it now with the *double, triple,* and even *heavier* electrolytic zinc coated Thomas Strip. This cold-rolled strip steel has a dense, uniformly distributed peel-proof zinc coating that adds substantially to product life and appearance. Coated edges can be furnished in most sizes.

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Design Abstracts

Types: The elastomers exhibiting the best flexibility at low temperature are the silicone rubbers. Some of these compounds are almost as flexible at −65 F as they are at room temperature. The silicone stocks compounded for low compression set, however, are not as flexible at −65 F and the designer must compromise.

Natural rubber and several of the synthetic rubbers can be compounded to give excellent low temperature service. Here compromises are again required. To get the best toughness, a natural rubber stock will probably be selected and weather, oil and fuel resistance will immediately be compromised. A coating of thin chloroprene could be applied to tubular parts, which would increase resistance to weathering and damage from spilled engine oil. A second coating, usually a silicone grease, may be required to keep the first coating from sticking to metal surfaces. Hydraulic oil or fuel will quickly delaminate the chloroprene coating.

Silicones Weather Best

To get the best weather resistance in a low-temperature stock, silicone rubber would again be selected but would sacrifice toughness. The next best would be coated natural or nitrile and if coating was not practical, as in a solid section or bumper seal due to the mechanics of coating, FR-neoprene would be used. This freeze-resistant chloroprene stock would not crack on low-temperature flexing but would be quite stiff, requiring high deflection forces, and would not be weather resistant.

To get low temperature and fuel resistance would require a nitrile compound. Here a compromise in fuel resistance must be made, as the plasticizers which impart good low-temperature flexibility are generally extractable in fuel. For a −40 F compound the swell-shrink range is generally not over 50 per cent of the original volume of the compound; that is, for a room temperature exposure the swell on fuel immersion may be +35 per cent and the shrink on drying might be as much as −15 per cent. By add-

ing the extreme low temperature flexibility requirement the swell-shrink range would be greatly increased. To overcome this difficulty on O-ring seals a special AMS committee is testing −65 F flexible compounds and will establish a procurement specification covering the best possible combinations of these properties. The chemical and petroleum industries are developing new non-extractable plasticizers for this group of compounds.

Design Applications: There is no "universal" compound which will meet all of the design requirements. Optimum performance in one requirement often must be sacrificed for serviceable requirements in another. Therefore, the engineer must review his application with a thoroughly critical eye to determine, first, what the part must do to function properly; second, under what conditions of exposure and temperature it will operate; and third, what conditions it will be subjected to when not in actual operation. Sometimes this last factor is the most important of the three, and this nonoperational condition will dictate the polymer that should be used.

Installation Methods: The method of installation of an elastomer is almost as important as the selection of the basic polymer. In fact, the selection of the polymer is often dependent on the attaching method. No matter how ingenious the design, a part is worthless if it cannot be installed, or if it is weakened or broken during installation.

Cementing is a commonly used technique for attachment. If a part is designed for cementing, no additional attachment is required; however, the cement joint is only as good as the cleanliness of the surfaces before the application of the cement.

Mechanical attachment is often used to supplement cementing, or may be used alone. Any device that overstresses the elastomer should be avoided, therefore slow drawup fasteners are best. Screws, small cherry-rivets or rivet-nuts are excellent. Drive or squeeze riveting damages the elastomers and the rivets soon work loose from cold

flow or compression set. The torque of screws or bolts is important for this same reason. A 60-durometer elastomer should not be subjected to more than 40 inch-pounds of torque, or extrusion of the elastomer may result. Explosive rivets were tried on one tubular seal, but proved to be too powerful, they blew a hole in the other side of the tube. They should be satisfactory on flat seals however, but screws would be better.

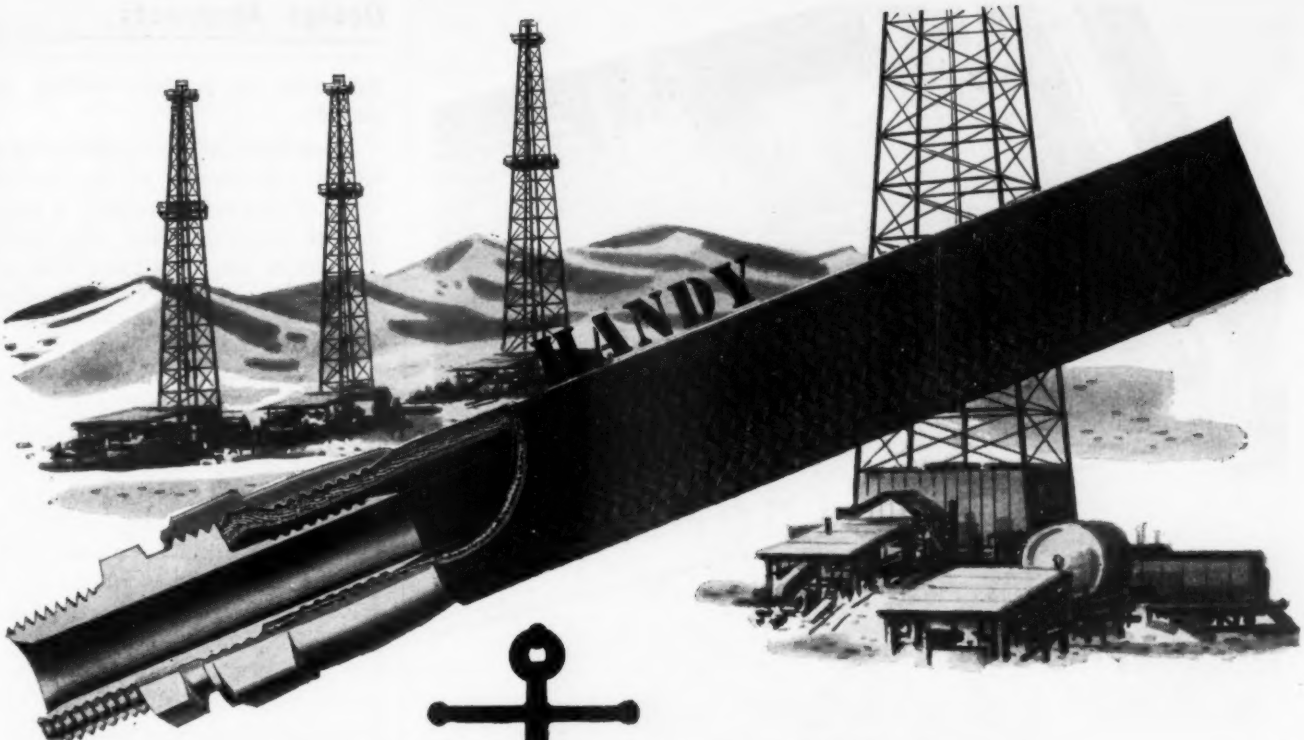
A back-up strip should always be applied either under the head of screws or the driving side of the cherry or rivnut. This strip can be thin aluminum, 0.016-inch or thereabouts. It distributes the load of fastening over a larger area of the seal and provides support between fasteners. Back-up strips can even be used inside of tubular sections with Trimount fasteners or other push-in-place attachments. Small Cherry-rivets, Rivnuts or similar blind fasteners are satisfactory if the height of the fastener inside the tube does not interfere with the deflection of the seal.

From a paper entitled "Elastomers—Rubber-Like Materials" presented at SAE National Aeronautic Meeting in Los Angeles, Calif., October 1952.

Magnetic Amplifier Development

By R. A. Ramey
Magnetic Development Section
Materials Division
Westinghouse Electric Corp.
East Pittsburgh, Pa.

HISTORY of the development of magnetic amplifiers is surprisingly old. The first magnetic circuits were invented somewhere about the turn of the century. References have been found in patent literature dating about 1910 where the circuits in their original form were presented as components of systems. In 1916 magnetic amplifiers were being used for, of all things, radio communication. The experiments of Alexanderson led to the development of units capable of modulation of 72 kw of radio frequency power. Alexanderson of course used rotating equipment at



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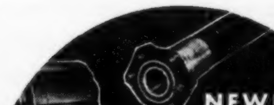

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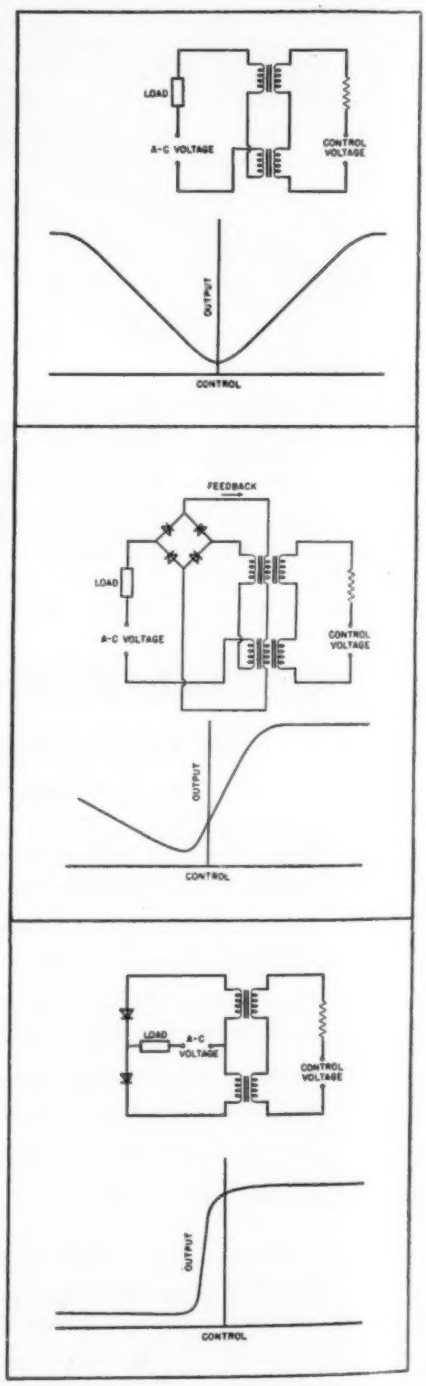
this time to produce carrier frequency.

Basic Circuits: Circuitwise the essential chronology of the development of magnetic circuitry is shown in the accompanying illustration. The series amplifier came first as a cross connection of two transform-



Chronological development of magnetic amplifier. Series amplifier, top, came first and was followed by the external feedback type, center. Present type, bottom, employs a self-saturating circuit

ers. In this configuration, dc current in the control winding regulates the flow of ac current in the load winding. One of the major drawbacks of this circuit is the requirement that the control ampere turns equal the load ampere turns. This is a major limitation to the possible gain which can be realized. A practical circuit might have a power gain of 10 to 100 with response time in the order of 5 to 50 cycles of ac power; that is, perhaps a second with 60 cycle power for reasonable gain. The gains quoted would not be too hard to live with. The real killer is the slow response. An amplifier must respond rapidly in a control system to be effective. So a figure of merit has been devised—the ratio of gain to speed—which describes an amplifier's performance. On this scale, the series amplifier may have a figure of merit of four. Gain and speed of response in magnetic circuits are inverse functions; the higher the gain, the slower the amplifier.

The next step in the development of these circuits was the external feedback amplifier. Here load current is rectified and sent through a control-connected winding producing the required control current. This resulted in a tremendous increase in the obtainable gain and had the effect of increasing the figure of merit since the gain increase far exceeds the additional delay time. A figure of merit of possibly 500 is available, using the best magnetic materials and rectifiers in this circuit.

The currently popular self-saturating circuit exemplified in the illustration gives the most effective design to date. In this type of circuit, the control winding is practically relieved of carrying ampere turns due to the load ampere turns. Only the magnetizing current, determined by the magnetic material, needs to be carried by the control connected windings. Here is a circuit relatively cheap to fabricate which gives excellent performance. The figure of merit of this configuration can be made well over 1000.

Historical Background: We went into World War II hardly realizing that such equipment existed. The

Design Abstracts

Germans had a slightly different viewpoint. They were preparing for war long before. They started in the early 1930's to apply magnetic amplifiers wherever possible to their war machine, realizing the inherent advantages that could be obtained. No notable changes were made in circuitry. It remained the same as originally invented in America. After the war this German equipment was examined. On their vessels of war, control panels were found which had been installed on the ships when they were originally built in the thirties. The panels had never been opened, yet they functioned beautifully. This is startling when one considers the continuous need for service on electronic equipment. Evaluation of the German equipment showed their performance to be not only mediocre, but relatively poor.

Publicity Influential

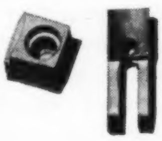
The publicity, however, which revealed the reliability, freedom from maintenance, and ruggedness of this equipment under extreme conditions, incited organizations to begin investigating magnetic amplifiers. The Armed Services, through their research laboratories, have greatly facilitated these studies. Particular credit is due the Naval Research Laboratory and the Naval Ordnance Laboratory.

Basically, these circuits consist of wires wound on iron cores and dry-disk rectifiers. Superficially, examination of such circuitry would indicate that nothing could possibly be wrong with it and it should be practically maintenance-free; it should be able to withstand wide temperature ranges; and it should be proof against practically all environmental difficulties. This is a goal indeed when one considers that the electronic equipment it proposes to replace has a particularly terrible maintenance record.

From a paper entitled "The Influence of Materials on Magnetic Amplifiers" presented at the second editorial conference on Trends of Electric Power in Industry sponsored by the Westinghouse Electric Corp. in East Pittsburgh, Pa., November 1952.

Which of These Precision Investment Castings Now Saves Money for Your Industry?

Industrial Heating — This atomizer nozzle for oil furnaces used to require machining in five parts. By precision casting it can be made in three. "S"® Monel is used for corrosion and wear resistance and resistance to steam erosion.



Power Equipment — If these carbon steel parts for the trigger mechanism on power tools were machined, a year's supply would have to be made. Parts are now made by precision casting in monthly quantities and at a saving.

Aeronautical — Power recovery buckets are precision cast of cobalt alloy to promote strength and resistance to exhaust gases. This alloy has a Rockwell C hardness of 27 and would be extremely costly to fabricate.

Food Processing—This collet spreader for a liquor dispenser is precision cast of Inconel® to prevent metallic pick-up from causing discoloration of the liquor. If made by machining methods the cost would be much higher.

Gun Manufacturing — This cartridge stop for a shot gun is made of tool steel for wear resistance. Precision casting was used to save the high cost of machining.

Chemical — Here's a precision cast valve stem for railroad tank cars. It was cast in Monel® to resist corrosion by chlorine. Previous fabricating methods cost nearly twice as much.

Instrument Manufacturing—This gyroscope gimbal is precision cast in carbon steel to insure strength. It would be impractical to die cast this hard metal.

Electrical—Here's a carbon jaw for a motion picture projector. It's made of nickel to resist spark erosion and give long service life. Saving of scrap metal by precision casting makes possible the use of this higher alloy at little additional cost.

Surgical Equipment — Another example of how precision castings save high machining costs in this stainless steel lug for stomach suturing apparatus.

Sporting Goods — This little gadget would be prohibitively priced if made by conventional methods. It's a pick-up finger for a fishing reel and is precision cast of "H"® Monel to resist corrosion by sea water and air.

SOME ALLOYS PRECISION CAST BY INCO

- Nickel-Base Alloys
- Ferrous Alloys
- Austenitic Stainless Steels
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- Ferritic Stainless Steels
- Carbon Steels
- Alloy Steels
- Cobalt-Base Alloys

These examples show a few of the many places precision investment castings are used.

They can save as much as 50 percent of production cost. They reduce machine shop bottle-necks, make possible use of extremely hard metals, permit production of designs impossible to fabricate by other methods and frequently lend to economies through re-design. Since they reduce metal scrap, they often permit the use of a higher alloy which otherwise would be too costly.

Whenever you have a part which is 6" x 5" or smaller, weighs under 3 lbs., requires tolerances as close as plus or minus .005" per linear inch, and would need 5 or more fabrication steps, there is a good chance you can cut costs by having it precision cast.

For more information, write for your free copy of "Investment Casting—Its Advantages and Practical Applications." The International Nickel Company, Inc., 67 Wall Street, New York 5, N. Y.

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New Machines

Heating and Ventilating

Air Conditioners: Two room type models, one for floor and another for ceiling mounting, for use with central systems. Units heat or cool with water piped from a central source; are available in capacities of 200, 400 and 600 cfm. Direct expansion units also available as well as window type models in ¾ and 1-hp sizes which feature one-dial control, directional air flow and automatic step-down control for night operation. *Worthington Corp., Harrison, N. J.*

Portable Heaters: Direct heat across floor and ground areas. Model L has tank, burner, blower and pump; requires no chimney. Model H may be used unvented or connected to a chimney. Output of each model is 175,000 Btu. Units can be adapted to circulate cool air by changing position of blower. *Mortemp Heat Machine Co., Seattle, Wash.*

Materials Handling

Fork Lift Truck: Gas powered, pneumatic tired; has 10,000-lb capacity at 24-in. load center. Designed for heavy-duty high tiering under difficult outdoor conditions. Has 133-in. turning radius, hydraulic steering. Honed cylinder surfaces, double-acting tilt cylinders, piston type hydraulic system, rubber dust boots. Overall height, 113 in. with fork lowered, 178 in. maximum with forks raised to 144 in. *Clark Equipment Co., Industrial Truck Div., Battle Creek, Mich.*

Overhead Carrier: Load capacity, 3 tons. Equipped with lever-operated hydraulic cell scale which carries the upper hoist block. Load pressure is transmitted from cell to scale dial by hydraulic tubing. Travel speed of carrier is 300 fpm; hoist speed is 38 fpm; lift is 36 ft. Both travel and hoisting motors have variable-speed controllers. Hoist controller is designed for dynamic lowering. Limit switch per-

New Machines

mits travel only when load block is in high position, assuring clearance through openings of limited dimensions along travel route. *Cleveland Tramrail Div., Cleveland Crane & Engineering Co., Wickliffe, O.*

Material Handling Truck: Lightweight "Xpediter" designed for handling boxes, barrels, castings, machined parts, etc. Can be used on elevators and floors where heavy units cannot operate. Driver rides on pedal platform. Available in six models, with hydraulic and manual lifts, to handle loads up to 800 lb on a 12-in. load center. Will operate in 56-in. aisles; turns in 68-in. radius. *Kalamazoo Mfg. Co., Kalamazoo, Mich.*

Load Pusher: Attachment for fork trucks designed to handle bulky, unpalletized loads. Loads highway carriers unable to accommodate fork trucks because of floor load capacities or limited clearance. Installation on a fork truck reduces load capacity only about 10 per cent. Available on lift trucks having capacities from 2000 to 6000 pounds. *The Baker-Raulang Co., Baker Industrial Truck Div., Cleveland, O.*

Metalworking

Tool and Cutter Grinder: Sterling Model "G" has cast base which is designed to dampen vibration. Wheel head rotates 360 degrees; work table swivels 180 degrees. Swing over the table is 10¾ in. Maximum distance between centers with left or right-hand tailstock is 27 in. Controls are located so that machine can be operated from front, left or right-hand sides. Available in both plain and universal machines. Universal machine features power table traverse and automatic table infeed. *McDonough Mfg. Co., Eau Claire, Wis.*

Band Saw: Zephyr Model CO-36 for heavy-duty cutoff work. Will handle ferrous or nonferrous metals in all shapes including plate, structural, ingot, slab, pipe, extruded or rolled forms. Saw blade is twisted 90 degrees from conventional position at the work table; work is fed to blade from front of machine. Throat capacity does not limit length of stock that can be

cut. Machine converts to conventional high or low speed, straight or contour sawing. Accommodates $15\frac{1}{2}$-in. work thickness under saw guides and $9\frac{1}{2}$ in. thickness at the column. Hydraulically powered 40 by 48-in. work table can handle up to 2000 lb. Tool speed range from 40 to 10,000 fpm is provided by a three-speed transmission and 10-hp variable speed drive. High-speed, friction or conventional low-speed sawing is possible. Other features include automatic floating-disk hydraulic brakes; job selector, band speed and tension indicator dials; air pump and chip blower; double-row ball-bearing high-speed saw guides; replaceable insert type guides for conventional contour sawing. Special clamping vise is provided for T-slotted work table. *The DoAll Co., Des Plaines, Ill.*

Hydraulic Gap Presses: New line of electrically-powered presses available in 11 standard forcing models and 11 standard straightening models with capacities ranging from 15 to 300 tons. Straightening presses have a self-contained power unit and adjustable stroke control. Combination hand and foot lever provides sensitivity which permits operator to apply any pressure up to maximum by increasing pressure on control valve. Forcing presses have two-speed ram advance and extra large table. Stroke can be preset for both directions by an adjustable stroke limit cam. *Dake Engine Co., Grand Haven, Mich.*

Punch: No. 10 Guillotine plate and angle punch for punching angles, webs of sections or flat plates. Capacity is 250 tons. Distance between housings is 74 in.; ram is 72 in. long, 24 in. wide. Ram stroke is $2\frac{1}{2}$ in. *Beatty Machine & Mfg. Co., Hammond, Ind.*

Bending Rolls: All steel; produce cylinders from thinnest sheets to maximum capacity. Can also roll bends in various shapes including oval forms, rectangular pipes, rounded-end containers and cones. Pinch type construction reduces flat spots on leading and trailing edges of work. Air-operated drop end is controlled by a two-position valve. Upper roll automatically tilts for removal of rolled cylinder. Power

New Machines

adjustment for rear roll allows operator to move roll to proper position for producing any desired radius of curvature. Roll position indicators permit duplication of roll setting for repeat jobs. Magnetic brake on main motor prevents "drifting" of work, permits rapid reversal and positive jogging of rolls. Rolls are made in three sizes, with capacities of 5/16 by 48 in., 3/16 by 72 in. and 12 gage by 120 in. *Niagara Machine & Tool Works, Buffalo, N. Y.*

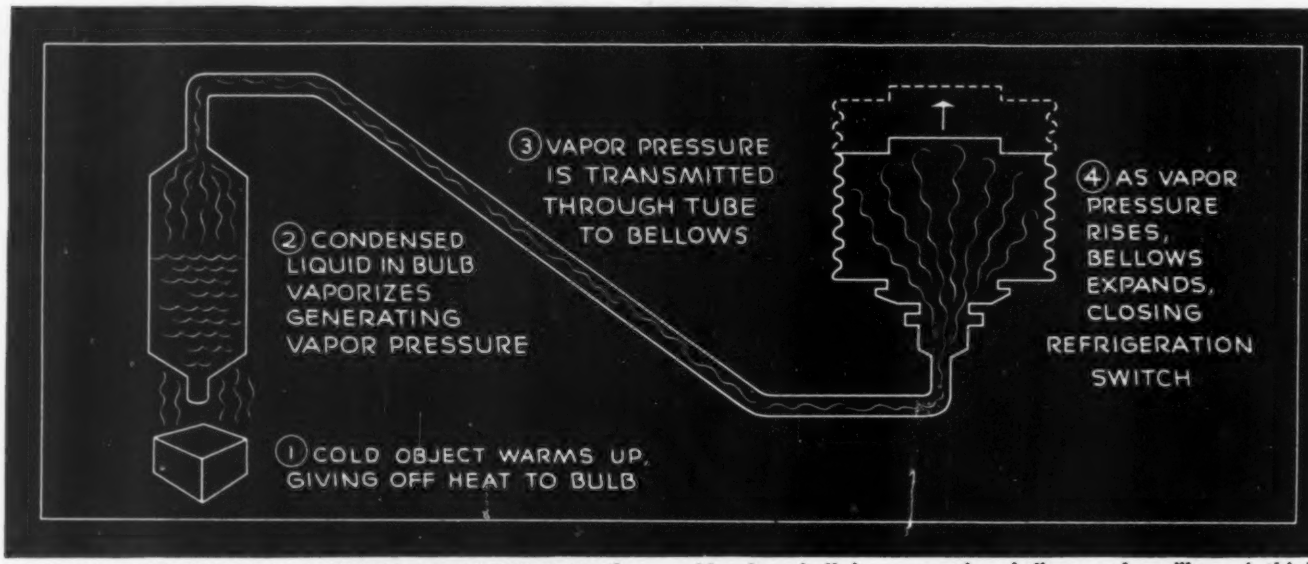
Turbine Blade Grinder: Double-spindle machine rough grinds parallel ends of turbine blades. Machine consists of heavy cast iron base supporting two grinding heads upon dovetailed slides operating on ball-bearing ways. Rotary attachment carries work carrier having approximately 26 slots into which the turbine blades are loaded manually. Chain hold-down attachment holds workpieces in carrier during grinding operation. Pieces unload automatically after leaving hold-down. Production rate is 20 to 25 pieces per minute, removing 1/16-in. maximum stock per end. *Gardner Machine Co., Beloit, Wis.*

Boring Machine: Specially built for the complete machining of a jet engine compressor case. Two-piece design. Boring bar is rigid with a temporary support during loading. Tool slides are mechanically actuated and hydraulically controlled. Both halves of the housing are clamped in the fixture by a series of self-locking, spring-loaded blocks. Carriage advances work over boring bar, which is inserted in an outboard support bearing and the temporary support retracted. Cylindrical, tapered or combined bores and end faces, T-slots and other grooves can be machined. *Morey Machinery Co. Inc., New York, N. Y.*

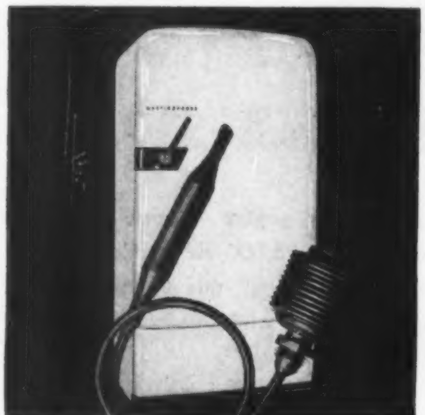
Carbide Tool Grinder: Uses special Dynatomic grinding fluid which reduces normal heat generation. Consists of high-speed spindle housing mounted on iron base. Spindle sleeve is spring suspended and rotates in gyroscopic float at operating speeds. Grinding wheel is of semisegmental ring shape, grinding on the front face. It mounts on

Bellows Digest

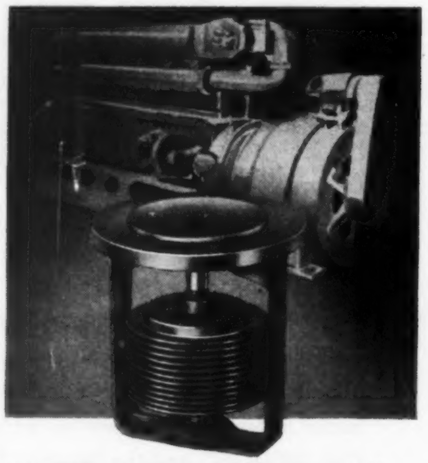
No. 2 Vapor Pressure Bellows System for Temperature Control commonly used for thermostatic devices requiring close temperature control



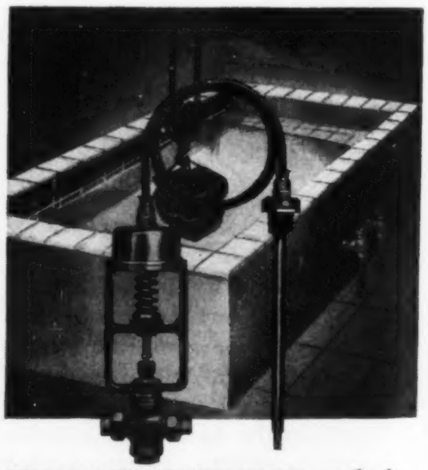
USED FOR THERMOSTATIC CONTROL OR INDICATION, the vapor-actuated bellows assembly above regulates refrigerator temperature. A similar system is available to control heating systems and can be made "fail safe" to prevent overheating if control fails. The system shown meets conditions in which bulb is always *colder* than bellows and capillary. Other systems available where bulb is *warmer* than bellows and capillary. A third system meets *either* condition—bulb colder or warmer than rest of system. Adjustment, generally obtained by spring-loading against pressure developed by bellows, is commonly limited to a lower range than liquid-filled systems, but sometimes allows a narrower differential. Only short bellows travel is required.



CLIFFORD VAPOR PRESSURE BELLOWS ASSEMBLIES have gained wide acceptance among refrigerator manufacturers. Westinghouse and other leading makers depend on these positive-acting components for the close temperature control essential to modern refrigeration.

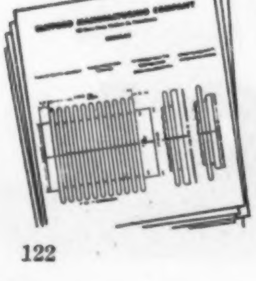


ALL TYPES OF DIESEL ENGINES, stationary and automotive, as well as truck and passenger car gasoline engines, are fitted with thermostats embodying Clifford vapor-actuated bellows assemblies. Simplicity, dependability and easy installation are major advantages.



TEMPERATURE REGULATORS made by Kaye & MacDonald, Inc., are used in water heating or cooling tanks, steam cookers, acid baths, glue heaters, bottle washers, tempering baths, other equipment. Clifford vapor pressure bellows assemblies are the actuating elements.

MAYBE YOU, TOO, CAN BENEFIT from the use of Clifford Hydron Bellows Assemblies. Besides controlling temperature, these flexible, leakproof, metallic bellows are also used to: (1) seal rotary shafts or packless valves against liquid or gas leakage; (2) transmit motion hydraulically to remote points; (3) provide for thermal expansion in many types of applications; (4) provide shock mountings or vibration dampening; (5) permit motion in a vacuum.



FREE! BELLOWS TEMPLATE KIT
Trace 20 most popular bellows sizes . . . fast . . . accurately. Kit, in handy cardboard envelope, includes full directions and details of Clifford bellows. Simplify tedious jobs—send for your Kit today.

Write Clifford Manufacturing Company, 124 Grove Street, Waltham 54, Massachusetts. *Division of Standard-Thomson Corporation.* Sales offices in New York 17, Detroit, Chicago 1, Los Angeles.

38.2.9

HYDRON METAL BELLOWS — CLIFFORD — HEAT EXCHANGERS

122

New Machines

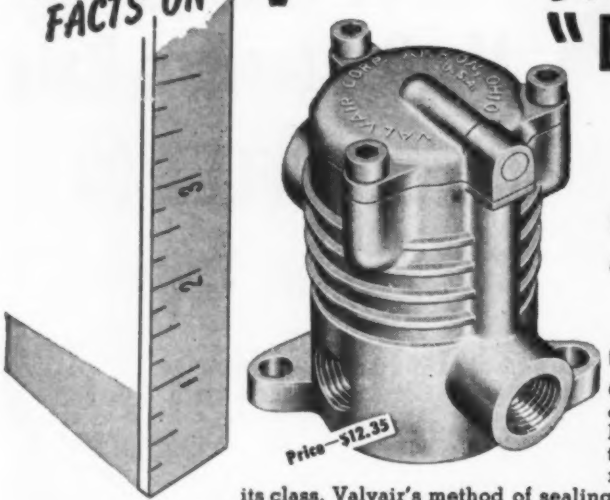
spindle nose and is encased in a steel clamp ring. Spiral teeth on periphery of clamp ring draw grinding fluid back to tank. Features include elimination of diamond wheels, simultaneous rough and finish grinding or shank steel and carbide grinding, easy operation. *Dynatomic Corp., Chicago, Ill.*

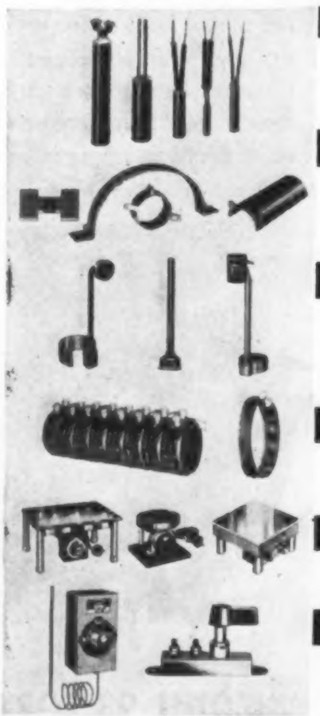
Contour Shear: Tru-Edge machine for inside cutting, beading and forming sheet steel. New shearing principle eliminates resistance to feeding and turning work. Feeding of material may be started while ram is operating. Inside cutting requires no starting holes, thus eliminates preliminary operations. Unusual cam operation eliminates vibration. Material is sheared instead of punched to provide smoothly cut edge. Adjustable bottom shearing die accommodates various thicknesses of material. Shearing capacity is up to 10 gage mild steel and 11 gage stainless steel. Cuts from 10 to 36 fpm, depending on gage and material. Throat depth of 48 in. can be increased by arranging centers outside throat. *Wales-Strippit Corp., North Tonawanda, N. Y.*

Drilling Machine: Redesigned two-spindle, 20-in. swing Model MC-20 has sturdier column and heavier base. Capacity is $1\frac{1}{4}$-in. in mild steel. Dial indicator which facilitates selection of geared power feeds increases operator efficiency. Spring-loaded lever for changing the eight spindle speeds from 65 to 1360 rpm reduces operator time. *Sibley Machine & Foundry Corp., South Bend, Ind.*

Packaging

Automatic Filling Scale: Designed specifically for use with resins, clay, powders and other light, difficult-to-handle materials. Model 600G automatically holds, fills, checkweighs and releases up to six full bags of material a minute within weight tolerances of ± 2 oz or less for any desired weight from 25 to 200 lb. Features air-operated bag holder, shockproof leverage system and a combination gravity and rotary feeding system. When feeding operation begins, 95 per cent of material to be weighed





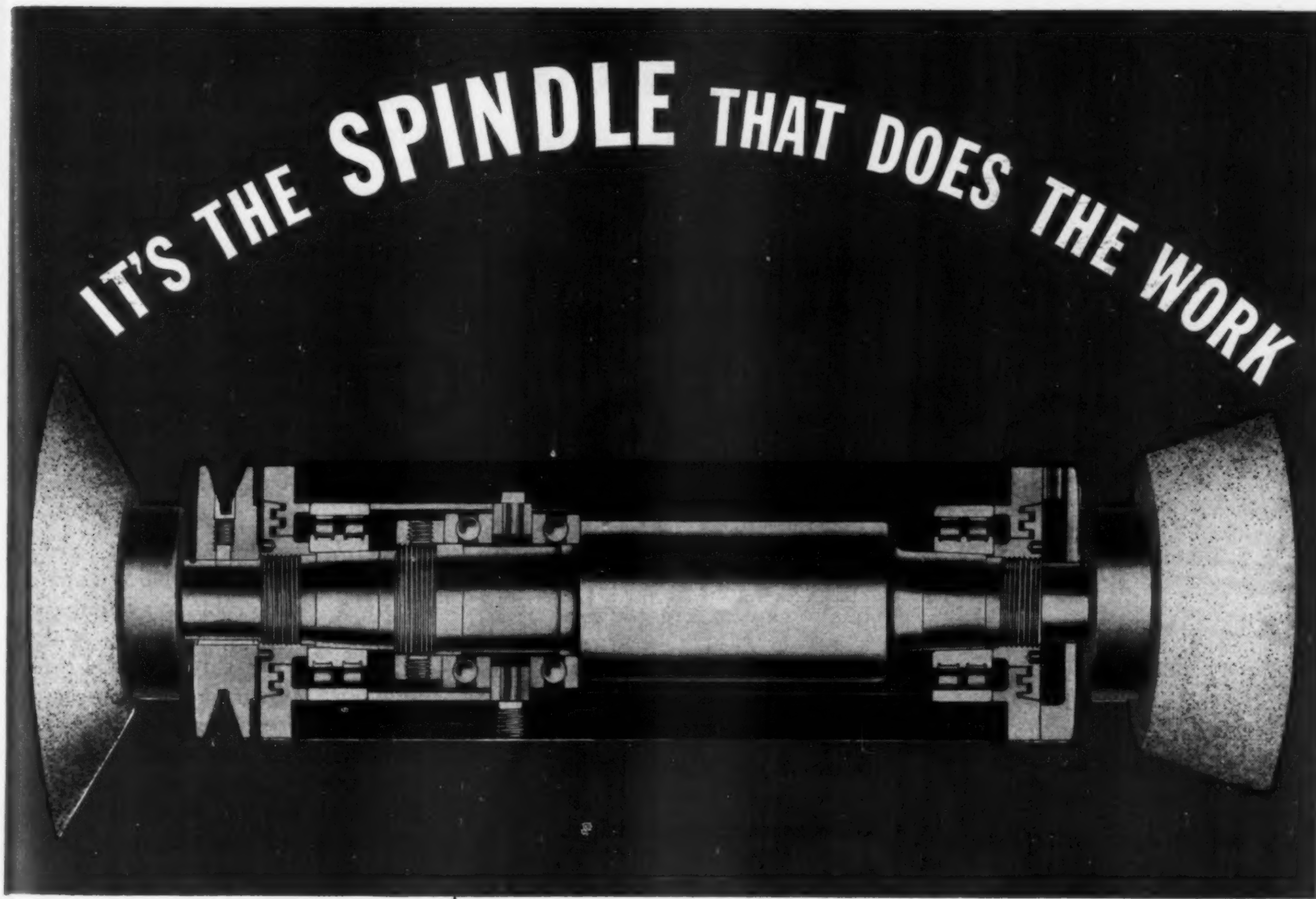
is fed into the bag by gravity and, if necessary, compressed air. Remaining 5 per cent is then fed slowly by a positive feed device until the bag reaches predetermined weight. Feed gate then automatically seals tight and checkweighing lights indicate that the bag is filled. Bag holder design provides space above bag for use when filling with materials which must be aerated. Overall dimensions of scale and feeder, 2 by 2 by 3 ft. *Thayer Scale and Engineering Corp., Rockland, Mass.*

Semiautomatic Weigher: "Clipper" accommodates 2-oz to 1½-lb packages; is accurate to within 1/32 oz on 4 oz or less, within 1/16-oz on larger weights depending on materials. Feeder is equipped with dialspeed control; provides uniform flow of material. Material to be weighed is placed in supply hopper, switch is turned on, valve gate is opened manually, and material flows into weighing bucket. When desired weight is in the bucket, flow automatically cuts off, material is dumped, and weighing of a new charge begins. Size, 48 in. high; base, 15 by 15 in. *Hannconn Machine Co. Inc., New York, N. Y.*

Plant Equipment

Gas-Oil Burner: Closed-flame unit features increased burning efficiency and simplified installation and servicing. May be used with any gas or oil fuel for firing industrial furnaces, ovens and process equipment in the operating range between 200 and 2400 F. Nozzle mixing principle employs a dual atomizing oil tip. Secondary air meets gas or oil mixture in both a converging and rotating pattern, promoting atomizing efficiency at nozzle exit. Rotating main combustion air casting permits adjustments for any desired alignment of piping. Burner has high discharge capacity and low turndown range. *Eclipse Fuel Engineering Co., Rockford, Ill.*

Compressed Air Filter: Model B-30-D Condensifilter dehydrates and filters ordinary plant air. Made of wire mesh to which flannel is attached, cartridge is of radial fin de-



P-32T

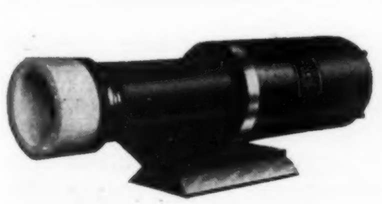
P-666

Specify POPE Precision Grinding Spindles and be certain of continuous production of finely finished parts.

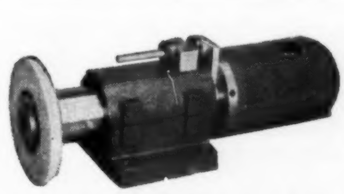
Look at the pair of thrust bearings. They eliminate any endwise movement of the shaft in either direction.

Look at the double row cylindrical roller bearings. They have the rigidity to properly support the wheel for removing metal faster while producing fine surface finishes.

Lubrication — POPE System — requires no attention for the life of the bearings.



P-10009



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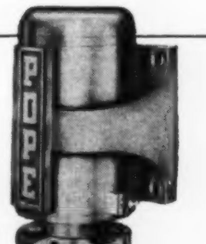

P-2500

No. 91

Specify **POPE**

PRECISION SPINDLES

POPE MACHINERY CORPORATION

ESTABLISHED 1920

261 RIVER STREET • HAVERHILL, MASSACHUSETTS

sign and provides over 540 sq in. of filtering area. Condensing unit provides greatest possible heat exchange area. As air passes over 400 sq in. surface area of condenser, its dew point is lowered to within 2 or 3 degrees of the cooling water temperature. Accumulated condensate is discharged through a trap valve, which is designed to prevent leakage or pressure loss even after long use. Rated capacity is 30 scfm at 100 psig. *Hankison Corp., Pittsburgh, Pa.*

Electric Plant: Air-cooled "CW" model is gasoline powered; available in 5000 and 10,000-w capacities. Vacuum cooling system employs centrifugal blower which draws cold air through generator and over engine and at the same time discharges heated air out of an 8 by 12-in. side vent. Features economy of operation, durability plus high output, simplicity of installation and maintenance, maximum safety. Requires less than 1 cu yd of space. *D. W. Onan & Sons Inc., Minneapolis, Minn.*

Vacuum Pump: Model G Microvac for high-vacuum evaporation of metals and metallic salts, evacuation of electric light bulbs, high-vacuum sealing of containers, etc. Features shaft seal installed to minimize maintenance. No stuffing boxes, valves or adjustments are necessary. Lubrication is completely automatic. Valve stops prevent springs from reaching coil-to-coil compression at any time. Side intake acts as baffle action against entering solids. *F. J. Stokes Machine Co., Philadelphia, Pa.*

Processing

ID Hole Quencher: Completely automatic. Heated die blank is placed into position on anvil and air-operated rams contact above and below, holding a fitting tightly against die. When proper contact is made, brine or other solution is pumped through die hole. When quenching is completed, a kick-out ram automatically pushes blank into tank for overall cooling. All timing, temperature and pumping operations can be set on a predetermined cycle. Can handle from 1/16 to 3-in. ID holes in blanks 1/4

Bundyweld Tubing

® DOUBLE-WALLED FROM A SINGLE STRIP

- Leakproof
- High thermal conductivity
- High bursting point
- High endurance limit
- Extra-strong
- Shock-resistant
- Ductile
- Lightweight
- Machines easily
- Takes plastic coating
- Scale-free
- Bright and clean
- No inside bead
- Uniform I.D., O.D.

WHY BUNDYWELD IS BETTER TUBING

Bundyweld starts as a single strip of copper-coated steel. Then it's . . . continuously rolled twice around laterally into a tube of uniform thickness, and passed through a furnace. Copper coating fuses with steel. Result . . . Bundyweld, double-walled and brazed through 360° of wall contact.

NOTE the exclusive patented Bundyweld beveled edges, which afford a smoother joint, absence of bead and less chance for any leakage.

Bundy Tubing Distributors and Representatives: *Cambridge 42, Mass.:* Austin-Hastings Co., Inc., 226 Binney St. • *Chattanooga 2, Tenn.:* Peirson-Deakins Co., 823-824 Chattanooga Bank Bldg. • *Chicago 32, Ill.:* Lapham-Hickey Co., 3333 W. 47th Place • *Elizabeth, New Jersey:* A. B. Murray Co., Inc., Post Office Box 476 • *Philadelphia 3, Penn.:* Rutan & Co., 1717 Sansom St. • *San Francisco 10, Calif.:* Pacific Metals Co., Ltd., 3100 19th St. • *Seattle 4, Wash.:* Eagle Metals Co., 4755 First Ave. South *Toronto 5, Ontario, Canada:* Alloy Metal Sales, Ltd., 181 Fleet St., E. • **Bundyweld nickel and Monel tubing is sold by distributors of nickel and nickel alloys in principal cities.**

to 8-in. OD and from 1/16 to 6 in. long. *The Palmer Mfg. Co., Cleveland, O.*

Die-Casting Machine: For up to 1½-lb zinc castings. Features electronically controlled panel, 10 by 10 by 2½-in. die blocks, four tie bars, semiautomatic cycling with adjustable timing dwell on opening and closing of toggle. Air operated; is capable of a free cycling speed of over 1000 shots per hour. *ABC Die Casting Machine Co., Chicago, Ill.*

Production Dipping Tanks: For hot-dip protective coatings. Five standard models range in size from 8 by 4 by 6 in. up to 13 by 6 by 18 in. Oil jacket is unnecessary because of positive agitation created by impeller agitator and special heating elements which radiate heat to sides of tank. Rapid heating and cooling is possible. Positive agitation eliminates surface congealing caused by ambient air and maintains transparency and color over longer periods. Melting time is less than 2 hrs on a 44-lb capacity tank. Tanks are available in a range of capacities from 6 to 1225 lb of plastic per load and can process as much as 2500 lb per eight-hour shift. *Globe Imperial Corp., Rockford, Ill.*

Centrifugal Casting Machine: Vertical, four-spindle, turntable type semiautomatic machine for making steel castings. Can also be used for ferrous and nonferrous castings in sand or permanent molds. Automatically indexes 90 degrees and stops. As spindle approaches pouring station it automatically comes up to spinning speed, metal is poured and a pushbutton operated to initiate indexing for the next 90 degrees. Poured mold spins until metal has solidified and is braked to a stop at casting removal station. Spindle then continues around to the next station where it is loaded with a mold, ready for pouring. Turntable is 10 ft in diameter. Each spindle is driven by a 5-hp, variable-speed motor with brake. *Centrifugal Casting Machine Co., Tulsa, Okla.*

Semi-Portable Degreaser: VS Jr model designed to clean small and medium sized parts; can degrease

Pages missing 305

up to 600 lb of steel per hour. Two models available, one electrically heated, the other steam operated. Parts are suspended in pure solvent vapor which dissolves dirt and grease. Spray of hot solvent flushes away loose soils, and a rinse in pure solvent vapor leaves work clean and dry. Work may be placed in baskets or on racks or hooks to facilitate handling. Work may be carried in and out of unit either by hand or a small hoist. Unit is 48 in. high. *Detrex Corp., Detroit, Mich.*

Surface Finishing Machine: Model 206-A for processing hand tools. Can produce finishes ranging from rough glaze to highly colored mirror reflecting surface. Equipped for either mechanical holding or the use of a magnetic chuck. Controlled by an electro-hydraulic system, the machine is of single-roll design. Spindle is 40 in. long, with buffs ranging from 3 to 12 in. in diameter. Optional V-belt drive of spindle permits variable surface speeds. When used with mechanical holding fixtures, machine provides working space 38 in. wide and 24 in. deep; largest available magnetic chuck provides working area 38 in. wide, 14 in. deep. *Clair Mfg. Co., Olean, N. Y.*

Heat Treating Unit: Model T-400 handles 400 lb of work per hour; features 100 per cent forced convection heating. Operates at temperatures up to 1850 F and has complete automatic straight-through operation from heat through cooling or oil quench. Sealed to provide absolute atmosphere control during entire heating and quench cycle. Employs non-alloy radiant heating tubes, baffles and a powerful fan mounted in roof of the furnace. Tubes are spring loaded and positively sealed by means of compression bellows and are designed for either gas-fired or electric heating elements. Work is loaded directly into heating zone, and after proper time at heat, work tray is automatically transferred onto a quench-cool rack which holds load for atmosphere cooling or lowers it for oil quench. Work tray moves automatically from heating zone to quench zone. Quench speeds and temperatures